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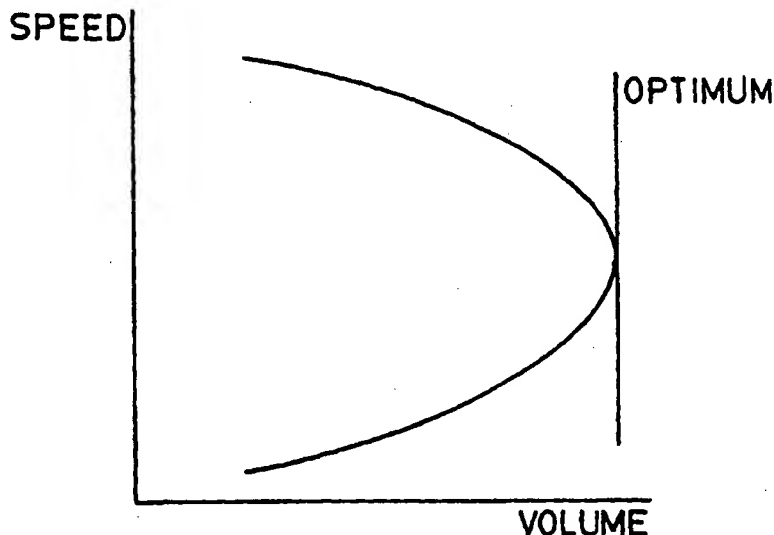
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[Continued on next page]

(54) Title: VEHICULAR TELEMETRY



(57) Abstract: The present invention provides a system for reporting on-board diagnostic data from mobile vehicles to regulatory agencies whose mandate it is to ensure compliance with environmental emissions and safety standards. The system comprises three (3) principal components: (i) an enhanced Hybrid Network Radio, enabled for both IEEE 802 wireless LAN connectivity and Mobile IP; (ii) an IEEE 802 Access Point, configured as an IPv6 Router and enabled for Mobile IP to support the functionality of foreign mobility agent; and (iii) a "cluster intelligence" module, incorporated in the same mobile device as the Hybrid Network Radio, using the Automotive Telemetry Protocol (ATP) to enable vehicles to exchange telemetry data with each other over an ad-hoc IEEE 802.11 network.

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VEHICULAR TELEMETRY

REFERENCE TO CO-PENDING APPLICATIONS

4,263,268
The subject matter of both provisional application serial number 60/056,388 filed August 26, 1997 and utility patent application serial number 09/140,759 filed August 26, 1998 (both entitled SYSTEM AND METHOD FOR PROVIDING MOBILE AUTOMOTIVE TELEMETRY) is incorporated herein by reference. The subject matter of PCT Application serial number PCT/CA98/00986 filed October 23, 1998 entitled TELECOMMUNICATIONS SYSTEM and designating the United States is also incorporated herein by reference. The subject matter of provisional application serial number 60/139,573 filed June 17, 1999 and entitled VEHICULAR TELEMETRY is also incorporated herein by reference. The subject matter of U.S. provisional application serial number 60/148,270, filed on August 11, 1999 and entitled VEHICULAR COMPUTING DEVICE is also incorporated herein by reference. The subject matter of U.S. provisional application serial number 60/187,022 March 6, 2000 is also incorporated herein by reference.

BACKGROUND OF THE INVENTION15 FIELD OF THE INVENTION

The present invention relates to data communications systems and more particularly to the field of vehicular telemetry using RF packet networks in conjunction with Internet or similar protocols.

DESCRIPTION OF THE RELATED ART

20 Hereinafter numerical reference is made to materials listed in Appendix A at the end of the disclosure.

Conventionally, vehicles have been known to exchange data with a diagnostic computer system (such as in a repair garage) over a hardwired or infrared data link, or a regulatory computer system (such as an electronic toll highway) by a data link using a low power transponder.

5 More sophisticated vehicular telemetry for commercial fleets has been made possible in the last several years through satellite RF packet networks. In these vehicular telemetry systems, vehicle sensor data can be transported over wireless data links to a computer that is programmed to monitor and record automotive phenomena and to support database systems for vehicular maintenance, without the need for the vehicle to
10 be in a particular service bay for example. However, these systems are relatively expensive to operate.

A considerable amount of research is being dedicated to developing feasible Intelligent Vehicle Highway Systems (IVHS) which are computer-assisted methods to manage highway infrastructures, synchronize traffic lights, measure traffic
15 flow, to alert drivers to ongoing traffic conditions through electronic billboards and other innovations aimed at improving the quality and efficiency of road transportation systems for vehicles.

The California Air Resources Board (CARB) has been a leader in establishing standards for monitoring vehicle emissions. A recent CARB initiative,
20 known as OBD-III, is the third generation of on-board diagnostic requirement, calling for an emissions regulatory agency to retrieve, remotely, diagnostic data from vehicles, thereby avoiding the need for a visit to a clean air inspection station. In one pilot program, a low-power transponder was used on each vehicle, capable of transferring data between the vehicle and a roadside receiver. Of course, in order for the OBD-III
25 proposal to proceed, each vehicle must have a system capable of collecting and dispatching the requested data through the transponder. CARB is actively reviewing

currently available technologies and is surveying the telecommunications industry to see what future equipment is planned. The operating platforms tested thus far by CARB have been relatively cumbersome and have limited capability to be used for other data exchange needs in the future. There is interest in finding a platform that will be
5 economical to operate in order to minimize the financial burden placed on the consumer to implement the proposal.

Moreover, it would be desirable for the chosen platform to be capable of doing more than just sending diagnostic information to a clean air agency. Both the telecom and auto industries are looking at ways to utilize the tremendous business
10 opportunities of reaching urban commuters in their vehicles while they devote several hours each day to their commute.

Vehicular traffic has become a major problem for urban planners. With land values skyrocketing and land-use issues becoming more of a concern, planners are looking for ways of getting more vehicles through existing commuter arteries as an
15 alternative to expanding them. It is also known that the actual volume of traffic handled by a thoroughfare plummets when traffic becomes congested. Therefore, it would be desirable to have vehicles which are capable of exchanging data with themselves as a way to control such things as safe driving distances to avoid collisions and exchanging data with traffic monitoring systems to control such things as driving speeds.

20 It is therefore an object of the present invention to provide a improved platform for vehicular telemetry.

It is a further object of the present invention to provide an improved vehicular telemetry system which is relatively inexpensive, yet capable of exchanging a range of useful data through a data communications system between a vehicle and a fixed
25 location.

It is still a further object of the present invention to provide a vehicle communications system in which the vehicles therein are each capable of communicating both through a data communications system and with themselves.

5

SUMMARY OF THE INVENTION

Briefly stated, the invention involves, in one of its aspects, a method of exchanging data between a mobile node and an access point on a communication network, comprising the steps of:

10

a) providing at least two data links between the mobile node and the access point;

b) measuring impedance on each data link; and

c) transmitting said data across the data link having the lowest impedance.

15

Preferably, the data links are wireless and a first of the data links is established on a spread spectrum radio frequency (RF) band. The data links may also comprise a satellite RF packet network or a terrestrial RF packet network. It is contemplated that other data links may become available in future as wireless data communications evolve.

20

In another of its aspects, the present invention provides a communications system, comprising

a mobile communications network having a mobile node,

a fixed communications network having an access point,

a pair of alternative data links, each of which joins the mobile node with the access point, and

a switching unit for switching between the alternative data links to exchange data between the mobile node and the access point.

5 In one embodiment, the mobile communications network includes a plurality of vehicle-mounted mobile nodes wherein at some are Internet addressable, for example under IPv6 protocol. Each mobile node and selected ones of the access points operate under the IEEE 802.11 standard. In this case, the data link joins each mobile node with at least one access point on a spread spectrum band. At least some of the access
10 points are located adjacent a roadway.

Preferably, the system includes a measuring module for measuring impedance on each of the data links. In this case, the switching unit is operable to select the data link having the least impedance.

In still another of its aspects, the present invention provides a
15 communications network for exchanging data between a plurality of vehicles, comprising a computing unit onboard a corresponding vehicle, each computing unit being operable in a first phase to broadcast enquiry messages in a region surrounding the vehicle, a second phase to receive reply messages from other vehicles in the region, and a third phase to exchange status messages with selected ones of the other vehicles.

20 In one embodiment, each computing unit includes an IEEE 802.11 node and exchanges data using an SNMP-derived protocol. Desirably, each node is Internet addressable, such as by the IPv6 standard for example.

In still another of its aspects, the present invention provides a vehicle comprising an onboard computing unit which is operable in a first phase to broadcast enquiry messages in a region surrounding the vehicle, a second phase to receive reply messages from computing units of other vehicles in the region, and a third phase to
5 exchange status messages with computing units of selected other vehicles.

Preferably, the vehicle is operable in a fourth phase to exchange data with a remote site in the form of a non-mobile gateway, which routes communications between a wireless mobile data link and a non-mobile network.

In one embodiment, the computing unit includes an IEEE 802.11 node and
10 can exchange data with other computing units using an SNMP-derived protocol.

In still another of its aspects, the present invention provides a hybrid communications system, comprising a wired network portion and a wireless network portion, each having a network connection node, at least two data link means between the network connection nodes, and a switch means for enabling either of the data links for
15 data exchange between the connection nodes.

Preferably, the system further comprises measurement means for measuring impedance on the data links, the switch means being responsive to the measurement means for enabling the data link having a lower impedance.

In yet another of its aspects, the present invention provides a vehicle
20 communications system having a controller, a data pathway joining the controller with a plurality of vehicle components and means for establishing a data link with other vehicles within a given region surrounding the vehicle in order to exchange data therewith.

In still another of its aspects, the present invention provides an operational event-reporting system for use by a plurality of neighboring vehicles to support IVHS comprising a plurality of communication units, each onboard a corresponding vehicle to collect operational data from selected components thereof and to exchange data with the communication units of one or more of the neighboring vehicles.

Preferably, the system is capable of exchanging data related to the operation of the neighboring vehicles, for example, GPS position and heading, vehicle speed, braking or the like. Data of this kind can be useful for vehicle telemetry systems to provide, for example, collision avoidance.

In yet another aspect of the present invention, there is provided a method of exchanging data between a vehicle and at least one remote site, comprising the step of providing the vehicle with a transmitter and receiver capable of transmitting and receiving messages under an SNMP protocol. Preferably, the data exchange site includes a neighboring vehicle or an access point for a wired network, for example.

In one embodiment, the method further comprises the steps of:

- exchanging discovery signals with neighboring vehicles; and
- exchanging status data with selected ones of the neighbouring vehicles.

In yet another of its aspects, there is provided a system for transferring data between a vehicle and another data exchange site, comprising a pair of data link means, wherein at least one of the data link means has a varying signal impedance level and switch means for switching between the data link means so that the data is transferred on the data link means having the least impedance.

In yet another of its aspects, the present invention provides an extension of the hybrid RF packet network comprising:

- (i) an interface to an IEEE 802.11 data link integrated in the Hybrid Network Radio;
- 5 (ii) an IEEE 802.11 Access Point acting as an IPv6 router and a foreign mobility agent for mobile nodes implementing Mobile IP;
- (iii) an interface to a non-wireless subnetwork from which the Hybrid Network Gateway can route mobile-terminated traffic through an IEEE 802.11 Access Point; and
- 10 (iv) a cluster intelligence module, based on the establishment of ad-hoc networks between a vehicle and its IEEE 802.11 neighbors.

Preferably, mobile nodes that are ATP-enabled can exchange Internet traffic with regulatory agencies over license-free wireless data links (IEEE 802.11) whenever connections are established with Mobile IP-enabled Access Points. The cluster
15 intelligence module is operable using ATP from vehicular node to acquire information about the automotive behavior of any of its discovered neighbors.

In another of its aspects, the present invention provides a method of exchanging data between a mobile node and an access point on a communications network, comprising:

- 20 a) a step for providing at least two wireless data links between the mobile node and the access point;

b) a step for measuring impedance on each data link: and

c) a step for transmitting said data across the data link having the lowest impedance.

5 In still another aspect of the present invention, there is provided a method of exchanging data between a motor vehicle and a remote station, comprising:

a) a step for providing at least two data links between vehicle and said station:

b) a step for measuring impedance on each data link: and

10 c) a step for transmitting said data across the data link having the lowest impedance.

15 In still another aspect of the present invention, there is provided an inter-vehicle communications network, comprising at least two motor vehicles, each having an on-board control system, the system including monitoring portion and a spread spectrum radio portion and which is operable to exchange useful vehicle operational data with the control system of the other vehicle.

20 Preferably, each monitoring portion is capable of registering a vehicular event and each control system may, if desired, be operable with other vehicular override systems to override a vehicle function according to a vehicular event. Desirably, each control system includes a memory portion for storing vehicle operational data of the other vehicle.

In one embodiment, the network includes at least one, preferably more than one, remote station is located along a road way on which the vehicles are traveling. The remote station includes a spread spectrum radio portion to be capable of exchanging data with either of the vehicles and is also preferably an internet or intranet or other
5 network access point.

Conveniently, the vehicles are operable to exchange data using an SNMP-derived protocol and each vehicle is capable of monitoring vehicular events in its own region.

10 In still another aspect of the present invention, there is provided a motor vehicle comprising an onboard general purpose computer and a spread spectrum radio, the computer operable to monitor a number of predetermined operating characteristics of the vehicle, the spread spectrum radio operable to establish a data link with a radio in at least one other neighbouring vehicle, wherein the computer is capable of identifying at least one vehicular event from data received on the data link.

15 In still another aspect of the present invention, there is provided a computer program product for operating a programmable computer system on board a motor vehicle, wherein the system includes a spread spectrum radio, comprising a computer readable medium including the computer executable steps of:

- instructing the radio to issue a signal to a region surrounding the motor vehicle;
- 20 - monitoring the radio for reply signals from other vehicles in the region; and when a reply signal is received from another vehicle,
- establishing a data link with the other vehicle; and

- exchanging operational data with the other vehicle over the data link.

In yet another of its aspects, there is provided a mobile automotive telemetry system for installation on-board a vehicle, comprising:

5 (i) diagnostic means for monitoring operational functions of the vehicle and generating operational information:

(ii) memory for storing the generated operational information; and

(iii) a server, in communication with the diagnostic means and the memory, the server comprising:

10 (a) means to receive a request from a remote client for the generated operational information:

(b) means to retrieve the generated operational information from the memory means; and

(c) means to transmit the generated operational information to the remote client.

15 Preferably, the means to receive and the means to transmit are wireless communication means.

20 In one embodiment, the system further comprises an Internet access means and a means to transmit generated operational information to a remote client, in absence of a request from the client, when the generated operational information satisfies predetermined criteria. Preferably, the Internet access means is compliant with IP V6 internet protocol and allows the server to act as a mobility agent. Preferably, the system further comprises means to interface to a global positioning system (GPS) receiver.

As described hereinbelow, the Applicant's pending application, serial number 09/140.759 filed August 26, 1998 entitled SYSTEM AND METHOD FOR PROVIDING MOBILE AUTOMOTIVE TELEMETRY discloses a system and method for automotive maintenance telemetry. The system functions on a client-server architecture enabling a remote client to request information from an on-board diagnostic (OBD) module in a vehicle, such as that commonly referred to as the Electronic Control Module (ECM). The OBD module performs the role of 'server' by being programmed to interface with the ECM, and with any other sources of diagnostic information and then communicates the data to a requesting client, such as OEM suppliers, dealers or regulatory agencies.

The location of the requesting client can dictate how the data is delivered. For example, in the Applicant's co-pending PCT Application PCT/CA98/00986 filed October 23, 1998 entitled TELECOMMUNICATIONS SYSTEM, the OBD module may select a path of least impedance to deliver the data to the client. For example, where the client is land-based, such as, for example an emissions regulatory body, the OBD module may deliver the data either through a conventional RF packet network (such as over a cellular phone connection) or through an RF packet network using a Hybrid network as described in the above mentioned PCT application. However, the requesting client may in fact be another vehicle traveling along the same roadway as the server vehicle and may request data for such things as vehicle speed, braking, position and the like. The OBD module may convey the data over a wireless data link such as over the band known as the "spread spectrum band" as is described in the applicant's co-pending provisional application serial number 60/139,573 filed June 17, 1999, entitled VEHICULAR TELEMETRY and as specified in the IEEE 802.11 standard.

IEEE 802 Standards Family

The IEEE 802 family of standards specifies the methods for implementation of local area networks (LAN's) using both wired and wireless media. The IEEE 802.11 standard specifies the medium access control (MAC) layer and three separate methods for implementation of the physical layer (PHY) as a wireless medium.

5 IEEE 802.11 is intended to ensure inter-operability between multi-vendor equipment operating in wireless networks. As such, it is the basis for the interface specified herein enabling vehicular computing equipment to establish license-free data links with fixed stations.

10 The IEEE 802.11 standard specifies three different physical layers. use of Infrared light, Direct Sequence Spread Spectrum and Frequency Hopping Spread Spectrum. The band utilized for the Spread Spectrum technique is ISM (Industrial, Scientific and Medical) RF band, which is free of regulatory licenses in most of the world. Communications in the Spread Spectrum involve a coordinated change in frequencies, either by a "Direct Sequence" or a "Frequency Hopping" format.

15 The IEEE 802.2 standard, called Logical Link Control (LLC), specifies a method for addressing and control of the data link, independent of the underlying medium, and is applicable to all types of LAN's defined within the IEEE 802 family. Both 802.11 and 802.2 are incorporated herein by reference.

20 The IEEE 802.11 does not specify the handoff mechanism for a mobile node to roam from one Access Point to another. When both the IEEE 802.11 client and Access Points incorporate IPv6 implementations, including ND (Neighbour Discovery) and RD (Router Discovery), roaming clients are able to bind to (or to establish a data link with) the Access Points, where the latter take on the role of Foreign Mobility agents as defined in [3]. The Access Point acts as a mobility agent for the roaming client. The

25 Mobile IP specification therefore provides a solution to the lack of an IEEE 802.11 mechanism for coordination of roaming (handoff) between Access Points.

Automotive Telemetry Protocol

In one embodiment, data is exchanged between vehicles using a protocol herein called "Automotive Telemetry Protocol" (or ATP) and is based on Simple Network Management Protocol (or SNMP). The latter is commonly used in data communication networks to monitor and control switching equipment. SNMP is specified in [2], the contents of which are incorporated herein by reference. ATP is intended to function according to the same client-server model as SNMP, wherein the client issues the requests for information and the server issues the responses. Although the ATP makes use of the same formats of the requests and responses as SNMP, ATP implements a novel set of "object identifiers" which are required to encompass the OBD data requested, in contrast to the telecommunications equipment data exchanged in SNMP. For example, the object identifiers may, in this case, correspond to nodes on the Controller Automation Network (CAN) bus in the vehicle, such as the ABS system, emission control system and the like.

SNMP and its derivative defined herein, ATP, are efficient request-response mechanisms which require less bandwidth than Web-based data exchanges between client and server. The payload (i.e. the useful telemetry data) can be encapsulated within the maximum allowable frame sizes of the underlying data links. These protocols therefore do not require the overhead associated with fragmentation at the source, and properly sequenced reassembly of large messages at the destination.

IPv6 and Mobile IP: Dynamic topology of the new Internet

The well known "Mobile IP" specification defines a protocol that enables IPv6 datagrams to be transparently routed to mobile nodes in the Internet. This specification is provided in *Internet Engineering Task Force, Perkins, C. (ed.), "IPv6*

Mobility Support", March 1995 [3], the contents of which are incorporated herein by reference.

By definition, a mobile node is one that can connect to the Internet through any one of a variety of different access points, called *mobility agents*. Each mobile node is registered with one and only one mobility agent, called a home agent. When a mobile node attaches itself to the Internet through an access point other than its home agent, the access point is called a foreign agent. The Mobile IP protocol incorporates a mechanism for mobile nodes, when they are attached to a foreign agent, to register a "care-of-address" with the home agent. Thus, datagrams routed to the mobile node through the home agent can be re-routed to reach the mobile node at its current network location.

When a mobile vehicle is already equipped with radio-modem technology that provides a unique address on a wireless network, it is possible to assign a unique Internet address that can be reached through an IP router between the wired Internet and the wireless network. This is described in the Applicant's co-pending PCT Application PCT/CA98/00986 filed October 23, 1998 entitled TELECOMMUNICATIONS SYSTEM. This represents a static Internet topology because, although the vehicle is mobile, the IP router through which it is reached never varies. The topology of the wireless network itself is dynamic and supports the roaming required for a vehicle to establish contact with the network through different base stations and regional switches. However, at the IP level, this dynamic topology is not visible.

In contrast, the Mobile IP extension to the IPv6 specification allows for a dynamic network topology. It lends itself to the task of enabling communication from the Internet to a mobile vehicle through different foreign mobility agents. In the context of vehicular mobility, the role of mobility agent can potentially be adopted by any Internet node that has the ability to dynamically create a data link with a vehicle. To date, the

most efficient means available by which such data links can be quickly established are defined by the IEEE 802.11 specification for wireless LAN's (Local Area Networks).

A data link can be established between a mobile IEEE 802.11 node, implemented in the vehicle, and any fixed IEEE 802.11 node, called an *Access Point*, provided that both nodes incorporate full implementation of the IPv6 protocols, specifically the Neighbor Discovery protocol, (hereinafter referred to as ND) and the Router Discovery protocol (RD). ND and RD are specified in *Narten, T., Nordmark, E., and W. Simpson, "Neighbor Discovery for IP Version 6 (IPv6)", RFC 1970, August 1996*, [5], the contents of which are incorporated herein by reference. For every interface to a datalink implemented in an IPv6 node, in this instance a wireless IEEE 802 datalink, ND is required to ensure that neighbors, defined as other nodes which are "on-link" (i.e., capable of communications on the same datalink) can be dynamically identified as they appear. This is accomplished through the use of periodic broadcasts on the wireless medium, called Neighbor Solicitations, to which any recipient of the broadcast is required to respond, in such a way as to enable the broadcaster to identify the responder with a unique IPv6 address. An implementation of ND typically maintains a table of neighbors that dynamically changes as each new cycle of neighbor solicitation either reveals a new respondent or loses, through lack of response, a (previously) existing neighbor. RD is a specialization of ND, ensuring that on-link nodes capable of routing IP datagrams to other sub-networks, can be discovered.

Thus, the vehicle communications system, according to one embodiment of the present invention, is capable of handling the Mobile IP protocols over an IEEE 802.11 data link and, as a consequence, is capable of delivering vehicular diagnostic data under the requirements of OBD-III and of exchanging a wide range of data, including e-commerce transactions and the like, as well as data needed for such things as Intelligent Vehicle Highway Systems.

According to one aspect of the present invention, each vehicle has one of a number of Hybrid Network Radios (as described in Applicant's PCT patent application PCT/CA98/00986) which can effectively communicate with one another using the Mobile IP protocol over one or more wireless LAN's. In this particular case, then, Internet-addressable vehicles may roam between wireless LAN's and still be in the network.

Ad Hoc Network

By making the vehicular computers Mobile IP-enabled as described in utility patent application 09/140,759 filed August 26, 1998 (entitled SYSTEM AND METHOD FOR PROVIDING MOBILE AUTOMOTIVE TELEMETRY) as described hereinbelow, each vehicular system may be connected to the Internet through the IEEE 802.11 data link. When two or more vehicular computer systems are equipped with IEEE 802.11 interfaces and where each operates on the same frequency changing format, that is by using either Direct Sequence Spread Spectrum or Spread Spectrum Frequency Hopping, they can then communicate amongst themselves and thereby create an "ad hoc" network between them. The so-equipped vehicular systems can now support IP Neighbor Discovery, which enables all vehicles within range to recognize each other as "on-link" IPv6 nodes, provided that the adjacent vehicular systems are also compliant with IPv6. This means that useful information may be exchanged between adjacent vehicles by the use of spread spectrum frequencies. Therefore, the same UDP/IP mechanism, used to permit telemetry traffic to be encapsulated in IPv6 datagrams from any vehicle to a fixed-location host, can be used to permit telemetry traffic to be exchanged between vehicles.

This ad hoc network also enables mobile vehicles within range of each other to establish a "cluster intelligence", which is defined, within the context of the present invention, as an infrastructure for interactive vehicular control based on the same

request/response telemetry architecture described in utility patent application serial number 09/140,759 filed August 26, 1998 (entitled SYSTEM AND METHOD FOR PROVIDING MOBILE AUTOMOTIVE TELEMETRY).

In one embodiment, the system comprises the following components:

- 5 (1) Hybrid Network Radio, as specified in [4], supplemented by:
 - (a) Wireless LAN interface compliant with:
 - (i) IEEE 802.2
 - (ii) IEEE 802.11 interface
 - (b) IPv6 modules including:
 - 10 (i) IPv6
 - (ii) IVMPv6
 - (iii) IP Neighbor Discovery and Router Discovery
 - (iv) Mobile IP
- (2) IEEE 802 Access Point as an IPv6 Router
- 15 (3) *Cluster Intelligence* Module

The cluster intelligence module is intended to provide a means by which Intelligent Vehicle Highway Systems (IVHS) can be implemented without the need for electronic wiring of the highway infrastructure. Cluster intelligence is based on the establishment of an *ad hoc network* connecting vehicular Hybrid Network Radios.

- 20 Whereas the primary goal of the Hybrid Network Radios is to enable least-cost IPv6 communications of telemetry data required by environmental regulations, an *ad hoc* network among and between Hybrid Network Radios provides a platform on which vehicles can transmit real-time operational information to each other.

As a result, in those instances where the aim of IVHS is to control the spacing and speed of vehicles on highways, and therefore the volume of vehicular traffic flow, cluster intelligence offers a low-cost alternative to the conventional ideas proposed for highway infrastructure upgrades.

5 Figure 1 shows the classic relationship defined in traffic engineering between speed and volume on a road link. There is an optimum point along this curve where the volume is maximized. The speed at this point is defined as the "free flow" speed. Below this speed, traffic flow is congested. Above this speed, the spacing between vehicles required for safety results in profligate use of the roadway. At any point along
10 the curve, the volume-speed relationship represents the most efficient inter-vehicle spacing, given the braking distance required for safety, which can be achieved.

In one embodiment, the peer-to-peer telemetry architecture of [1] and as described below, supports the ability of vehicles to adapt their speeds in accordance with the optimal volume-speed relationship. The ATP protocol used between vehicles enables
15 each one to determine, among other things:

- (a) The distance(s) between it and the vehicle(s) immediately ahead of it (using GPS position and heading reports).
- (b) The speed(s) of the vehicles immediately ahead of it.
- (c) Application of brakes.

20 This information provides the enabling technology for all vehicles to engage in a cooperative effort to maximize traffic flow on electronically enhanced highways.

The term "Impedance" used herein is intended to be a measure of the "costs" of sending a datagram across a data link. This cost can include the monetary charges associated with the transmission of data across a wireless data link and are typically imposed by the operator of the wireless data network, as well as other factors such as, for example, the size of packet and the time of day, which of course will change over time. As is described in the PCT Application serial number PCT/CA98/00986 filed October 23, 1998 entitled TELECOMMUNICATIONS SYSTEM, the Impedance governs the functionality of the RF path switch. As impedance changes, the output of the RF path switch (i.e. the routing decision) can change. The sections entitled Error Reporting and Airlink Status Reporting describe the mechanisms whereby changes in impedance are reported to the RF path switch module.

BRIEF DESCRIPTION OF THE DRAWINGS

Several preferred embodiments of the present invention will be provided, by way of example only, with reference to the appended drawings, wherein:

Figure 1 is plot of traffic volume versus speed on a road link:

Figure 2 is a schematic view of a vehicle communications system:

Figure 2a is a schematic view of one aspect of the vehicle communications system of figure 2:

Figure 3 is another schematic view of the vehicle communications system of figure 2:

Figure 4 is a schematic view of one segment of the vehicle communications stem of figure 2:

Figure 5 is a schematic view of another segment of the vehicle communications system of figure 2:

Figure 6 is a schematic view of still another segment of the vehicle communications system of figure 2:

5 Figure 7 is schematic representation of a system in accordance with one embodiment of the present invention:

Figures 8 a) and 8b) are schematic representations of a system according to still another embodiment: and

10 Figures 9, 10, 11, 12, 13, 14 and 15 are schematic views of portions of still another embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Figure 2 illustrates a communications network for exchanging data between a plurality of vehicles, including vehicles 10 and 12 on a highway shown at H. Each vehicle has a computing unit 10a and 12a, the latter of which is shown
15 schematically in figure 2a. Each computing unit has a processor 10c which is connected via a serial port to a GPS receiver 10d, an IEEE 802.11 spread spectrum unit 10e, a cell packet data unit 10f capable of broadcasting and receiving data over a cell packet data network and a memory unit 10g. If desired, the components of the computing unit may
20 be integrated on the same board using application specific integrated circuits (ASIC's), as described hereinbelow and in U.S. provisional application serial number 60/148,270, filed on August 11, 1999 and entitled VEHICULAR COMPUTING DEVICE.

Referring to figure 2, each computing unit 10a, 12a broadcasts ND and RD messages in a region surrounding the vehicle as shown by the circles 10b, 12b. In the example shown in figure 1 three other similarly equipped vehicles labeled 14a to 14c are all within the region 10b and therefore are capable of receiving the broadcast enquiry messages from the vehicle 10. The vehicles 14a to 14c issue reply messages which are received by the vehicle 10. Similarly, vehicles 14b to 14f are within the region 12b of the vehicle 12 which in turn receives reply messages from them. These messages may include such things as vehicle speed and GPS information as well as status indicators such as acceleration or braking. In this manner the computing units 10a, 12a are able to determine the position and movements of neighboring vehicles.

Thus, the number of vehicles in the corresponding region for each vehicle will change over time with the traffic pattern. In this case, the computing unit for each vehicle can retain status data for each target vehicle while the vehicle is in the region and then erase the data for those vehicles that have left the region. The memory unit 10g can have allocations for storing data for each vehicle while the processor can manipulate the data to determine if any action needs to be taken. The processor also receives data from the ECM 10h which can include such things as emissions, braking, acceleration, speed and the like, that is, any function of the vehicle which is being electronically sensed, monitored or measured. Optionally, the processor may also pass off, to other vehicle systems, braking or other override commands for controlling the vehicle if necessary.

Located along the highway are a number of access points which are routers to a fixed communications network, in this case spread spectrum base stations. One of the access points is shown at 16. The access point 16 issues router advertisement messages with a region shown by the circle 16a. Therefore, vehicle 12, in the instant of time represented by the figure 1, receives the advertisements. In this example, the vehicle computing units 10a and 12a as well as the access point 16 are IPv6 addressable. Therefore, the vehicle 12 and the access point 16 may then exchange data which may

include Internet email and the like. The access point 16 may also convey status request data from a clean air regulatory body to the vehicle 12 which may then return the status data to the regulatory body through the access point 16 if the vehicle is still in its region.

Base station 18 provides a wireless data link to a proprietary RF packet network, for example that known as the MOBITECH network, or the like. This is a different data link from the spread spectrum data link operating at the access points 16. The computing units exchange data with the station 18 via the cell packet data unit 10f.

The GPS information from the neighboring vehicles may, for example, include Differential GPS (D-GPS). In the latter cases, the vehicle may more accurately measure the position of neighboring vehicles, relative to a reference GPS position which may be broadcast, for example, from the access point 16.

Global System

Figure 3 shows the overall system architecture. As will be described, Figure 3 illustrates how the IEEE 802 data link is incorporated into the hybrid mobile packet network and shows the path of Mobile IP communications between a mobile node shown at 10 and its home mobility agent, i.e., the Hybrid Network Gateway 230. Mobile node 10 is an embedded vehicular computing device functioning both as an OBD server [1] and as a Hybrid Network Radio [2]. The Hybrid Network Radio functionality is implemented through the interface 40 to the hybrid mobile packet network 250.

Fixed node 16 is a wireless communications base station implemented in accordance with the definition of a "foreign (mobility) agent" contained in [3]. Mobile node 10 and fixed node 16 share the same IEEE 802 wireless data link 15, which, from the perspective of the mobile node 10 and as will be described further below, is integrated as a "zero-cost" data link in the interface 40 to the hybrid mobile packet network 250.

Fixed node 16 may be, for instance, an embedded computing device permanently installed near a roadway and connected to a data communications network 210 via a stationary (non-mobile) backbone 220.

5 When a mobile node 10 comes sufficiently within range of a fixed node 16 to establish an IEEE 802 data link, Internet traffic, in the form of IP datagrams, may flow from the vehicle to any address in the Internet. This is called "mobile-originated" traffic. "Mobile-terminated" traffic can only reach the vehicle once the Mobile IP "care-of address" registration has been completed. This procedure, specified in [3], allows the mobile node to notify its "home (mobility) agent" that it can be reached through the
10 foreign (mobility) agent embodied in the fixed node 16. As a foreign (mobility) agent, fixed node 16 is, by definition, an IPv6 router.

The home mobility agent for mobile node 10 resides in the Hybrid Network Gateway 230. A Hybrid Network Gateway (HNG) is the stationary equivalent of a Hybrid Network Radio and is defined in [2]. HNG 230 has an abstract interface
15 240 to the hybrid mobile packet network 250, through which it can route Internet traffic to a mobile node. In order to ensure least-cost routing to a mobile node that has registered fixed node 16 as its care-of-address, interface 240 must also incorporate the data link associated with stationary backbone 220. This extends the hybrid mobile packet network to include a stationary data link.

20 In other words, the system has the capacity to carry out least-cost transfer data between the Hybrid Network Gateway 230 and the mobile node 10 in one of three routes:

- i) via the data link 15, the fixed node 16, the data link 220 and the stationary non-mobile data link 210; or alternatively

ii) through the hybrid mobile packet network 250, which itself can provide least cost switching between :

- a) a satellite Packet Network; or
- b) an RF Packet Network.

5

Ipv6 Communication Protocol Stack

The IPv6-based communications software infrastructure for a telemetry system in accordance with this example is shown in Figure 4. Figure 4 is a representation of the Hybrid Network Radio incorporating interfaces to an arbitrary number of RF packet networks, including an interface to a wireless IEEE 802 data link, integrated into a single abstract data link as specified in [4]. Figure 4 also shows the relationship between the Hybrid Network Radio and an IEEE 802.11 Access Point incorporating an IPv6 router implementation. In this scenario, mobile-originated Internet traffic (datagrams emanating from the Hybrid Network Radio) can be routed through the access point or alternatively through the hybrid mobile packet network 250 depending on 'cost'. Mobile node 10 is an IPv6 (Internet) node consisting of a protocol stack 20 in accordance with definition of a Hybrid Network Radio provided in [4]. Fixed node 16 is an IPv6 (Internet) router consisting of the router-specific equivalent of protocol stack, labeled 21. The components of protocol stack 20 are:

- (i) a combined RF packet network 30 that unifies all the wireless data links available to mobile node 10 into a single abstract data link capable of least-cost switching;
- (ii) an IPv6 module 60, in accordance with [6], the contents of which are incorporated herein by reference;

(iii) an ICMPv6 module 70, in accordance with [7], the contents of which are incorporated herein by reference, that provides the assembly and parsing mechanisms for the specific datagrams required by ND:

(iv) a Neighbor Discovery (ND) module 80, in accordance with [5], that enables mobile node 10 to dynamically discover other "on-link" mobile nodes, i.e., other vehicles capable of communicating on the same IEEE 802.11 medium; and

(v) a Router Discovery (RD) module 90, in accordance with [5], which enables mobile node 10 to discover dynamically IPv6 router 16.

Both the ND and the RD protocols require the broadcasting of, respectively, neighbor and router advertisement datagrams, defined in ICMPv6. These datagrams are sent to the interface 40 to the combined RF packet network 30. Broadcast datagrams can only be transmitted on data links that are broadcast-enabled. Typically, wide area RF packet networks do not support broadcasting initiated by subscribers, although they often allow multicasting to selected groups of mobile subscribers. Since IEEE 802.11 depends on broadcast frames to establish the data link, it should identify itself to interface 40 as broadcast-enabled, whereas all other RF packet networks incorporated in the combined packet network 30 should report that they are not broadcast-enabled. The intelligent switching mechanism of this interface, which ensures that datagrams are transmitted over the least-cost data link, will therefore switch all mobile-originated broadcast datagrams over the IEEE 802.11 data link.

In case of overlapping of the coverage areas of two or more Access Points, a mobile node may receive router advertisements from more than one fixed station, in response to its broadcast of router solicitations, providing it with alternative on-link

routes to use for outbound datagrams. Both neighbor and router discovery should rely primarily on unsolicited neighbor and router advertisements.

Registration of the "care-of-address" provides a means for requests from the OBD telemetry client to reach a mobile node via the foreign mobility agent, which, by definition, is an IEEE 802 access point. The maximum acceptable impedance values associated with these requests can be set such that the mobile-terminated ATP traffic that would otherwise incur costs traveling over RF packet networks, can be deferred until the "care-of-address" is registered with the home address.

Cluster Intelligence

The cluster object as an ATP client is a specialization of the generic SNMP client using the UDP/IP protocol. The ATP allows for message passing to the cluster object.

The establishment of an IEEE 802.11 ad-hoc network as a "mobile cluster" in accordance with the present example is shown in Figure 5. Mobile node 10 incorporates the User Datagram Protocol (UDP) module 100 and the ATP module 110. An equivalent mobile node 11, with equivalent UDP and ATP modules 101 and 111, respectively, can interact with mobile node 10 such that the automotive behavior of 11 is known to 10. This is accomplished through the mechanism of an ATP request issued by 10 to 11 and an ATP response from 11 to 10.

The interaction between any two mobile nodes is managed by a "cluster", which is an active object that registers with the ATP for reports from neighboring vehicles. Cluster 120 has container 130 of neighbors, or more precisely, "images" of neighbors. These neighbors are placed in the container when detected by the ND mechanism operating over the IEEE 802.11 data link, as shown in Figure 4. By

propagating the discovery mechanism in ND module 90 upwards through the UDP/IP stack. Node 11 becomes a member of Node 10's cluster when the ATP signals the cluster that a new neighbor has appeared. (The whole process can be repeated for mobile node 12, which becomes a second neighbor of node 10).

5 Registration of neighbors discovered through the ND requires an implementation of IPv6 that can be asynchronously notified of ND, which requires a "callback" method of IPv6 to be invoked when the neighbor's response to a solicitation request is being processed. The conventional processing of such a response is simply to update the cache of on-link neighbors known for that interface. However, the
10 requirements of cluster intelligence are that dynamic neighbor identification propagate upward from the subnetwork layer to an application port of the UDP/IP protocol stack.

 In this example, cluster communications over wireless data links is intended to take place only over the license-free spread spectrum band. The cluster object itself has "no knowledge" of the fact that there are alternative radio paths between
15 vehicles. However, when the cluster asks each new neighbor to transmit GPS position reports and automotive events in which it is interested, both the requests as well as the responses will travel only over zero-cost links - which are precisely the same links over which the ND operates. In others words, by virtue of the least-cost mechanism described in [4], a license-free wireless data link will always be the data link over which the ND
20 datagrams are transmitted. ND can and should be configured such that its maximum acceptable impedance level can only be supported by the license-free links. ND will therefore only discover neighbors that are on the license free links and cluster traffic that follows from this will travel only over these links.

 Provided that an implementation of cluster 130 is compliant with the
25 requirements for the interface to the module ATP 110, already specified in [1], the internal behavior of the cluster may vary depending on the design objectives and

implementation style for a specific vehicular device. The precise design of the methods (behavior) or the specification of other methods intended to process (and act on) information reports from neighboring vehicles is not within the scope of the present invention.

5 *Process Architecture*

Figure 6 illustrates the process architecture of the device comprising the mobile node. ATP client process 300 is part of the cluster intelligence module. Figure 6 illustrates the architecture of the processes, running on top of the UDP/IP stack, that provide all of the functionality of the system. These processes are:

- 10 (i) an OBD process, with the behavior of an ATP server.
 (ii) a Cluster Intelligence process with the behavior of an ATP client;
 (iii) a Mobile IP process, with the behavior specified in [3]; and
 (iv) a diagnostic data acquisition process.

ATP is registered with UDP module 330 through the *application port* 305.
15 Similarly Mobile IP process 310, which is responsible for registration of care-of-
addresses (i.e., addresses of foreign mobility agents) with home mobility agents, is
registered with UDP module 330 through the application port 315. The ATP server
process 320, registered with UDP module 330 through port 325, provides access to the
Diagnostic Information data Base (DIB) 340. This data base, similar to the Management
20 Information data Base (MIB) used by SNMP (from which ATP is derived), contains all of
the on-board diagnostic information obtained from the data acquisition processes 350
(Analog and digital signal processing), 360 (CAN-bus data processing) and 370 (GPS
receiver data processing).

Whereas the present invention does not limit the scope or characteristics of
25 possible cluster implementations, the behavior recommended for effective use of the ATP

to implement cluster intelligence within each vehicle is described by the pseudo-code below. The cluster is defined as an object that owns an ATP client process with a set of methods corresponding to the handling of each of the possible messages that could be received through the ATP.

5 In one example, the cluster's ATP client process would be:

```
ClusterProcess()  
{  
    while( TRUE ) {  
        pointer_event_object = Wait_Queue_Event_Signalled_By_ATP();  
10    pointer_event_object->Handler(); // behavior of event object  
        destroy_event( pointer_event_object)  
    }  
}
```

15 The cluster process blocks on an event queue, registered with the ATP, to which the ATP can append events relevant to the cluster process as they occur. These events are removed from the queue and processed on a first-in first-out basis. All events are treated as objects derived from a common base class within a virtual "handler" method, the internal behavior of which varies for each type of event. The handler method of the event is invoked by the cluster process when the event is removed from the queue.

20 The primary type of event which the ATP should signal to the cluster is a GPS position report from a neighbor. This implies, of course, that all nodes on the ad-hoc IEEE 802.11 network should broadcast GPS position reports. Other on-link nodes receiving these broadcasts should propagate the reports upward through the protocol stack to the ATP, which should signal an *Event_GpsReport* to the cluster.

Event_GpsReport_Handler() is the method invoked when the *GpsReport* signaled by the ATP is removed by the cluster process from its queue. The inputs to this method are:

(i) *ID_Remote_Vehicle* - which should be the unique IP address of the vehicle:

5 (ii) *GpsPosition* - which is a latitude-longitude coordinate pair, determined by the GPS receiver of the remote node and contained in the payload of the UDP segment received from the remote; and

(iii) *GpsHeading* - which is a heading determined by the GPS receiver of the remote node and contained in the payload of the UDP segment received from the remote.

10

Event_GpsReport_Handler (ID_Remote_Vehicle, GpsPosition, GpsHeading)

{

Remote_Vehicle = *GetRemote(ID_Remote_Vehicle);*

Proximity = *CompareGps(Remote_Vehicle, GpsPosition,*

15 *GpsHeading);*

If(Proximity) {

AtpRequest(Remote_Vehicle, speed, frequency, duration, amplitude);

AtpRequest(Remote_Vehicle, foot brake, 0, 0, 0);

}

20

}

Event_GpsReport_Handler carries out the following functions:

(i) Invokes the private function *GetRemote* using the input *ID_Remote_Vehicle*. (The term *private* signifies that the function is usable only

by the cluster module and is not accessible to "external" software modules). This searches the cluster's container of remote vehicles for the object matching *ID_Remote_Vehicle*.

(ii) Uses the private function *CompareGps* to determine whether this vehicle is within a specified distance threshold. This function takes as inputs:

- (a) pointer to the Remote Vehicle object; and
- (b) the new GPS position and heading.

The GPS position and heading of the remote vehicle are compared to the position and heading of the "local" vehicle. The "local" position and heading are maintained in the DIB (diagnostic information base). Since the ATP is a peer-to-peer protocol, cluster intelligence request/response exchanges can be symmetrical. The DIB can therefore be used by the ATP client to obtain GPS information for comparison with reports from remote nodes, as well as by the local OBD server to respond to cluster intelligence requests from remote nodes.

The output of *CompareGps* is a boolean variable (*Proximity*) indicating whether ATP requests to this remote are warranted because the vehicle is within a specified distance threshold to require preventive measures if there is a sudden change in speed. Since the implementation of cluster intelligence is not within the scope of the present invention, the internal algorithm of *CompareGps* is not defined here. However, it should be noted that any implementation of *CompareGps* must account for margins of error in the accuracy of the GPS receiver where the remote position report originates. Furthermore, it may not be possible to distinguish between several remote vehicles moving in parallel in different lanes ahead of the "local" vehicle so that the identity of the

vehicle directly in front may remain indeterminate. The cluster intelligence decision algorithm may have to assume that all of these vehicles are equally important to monitor.

If Proximity is TRUE, then ATP requests can be issued to the remote node's OBD server, the responses to which enable the cluster to provide decision support to other intelligent modules within the complete automotive system. A minimum set of requests could consist of speed reports, at values of frequency and duration established by the owner of the cluster, (i.e., one of the aforementioned automotive modules), and of notifications for the application of the foot brake.

Another embodiment of the present invention is shown in figure 7. A mobile automotive telemetry system is shown generally at 110 in Figure 1. System 410 comprises a diagnostic means 415 for monitoring the operational functions of the vehicle in which system 410 is installed and generating operational information. The generated operational information may be stored in a memory 420 until required. Both diagnostic means 415 and memory 420 are in communication with a server 425 which ultimately controls the operation of system 410.

Server 425 can communicate with a remote client 430 via a data link 435. To this end, server 425 comprises a means (440) to receive a request for information from remote client 430; a means (445a, 445b) to retrieve the generated operational information from memory 420; and a means (450) to transmit the retrieved generated operational information to remote client 430. Server 425 is a processor which is programmed to respond to requests for information from remote clients and to respond to control commands.

Diagnostic means 415 may be a conventional, computer-based OBD module which monitors various operational functions of the vehicle in which system 410 is located. Diagnostic means 415 may, for example, monitor exhaust emissions, fuel use,

ignition timing, engine temperature, speed and/or distance travelled. Diagnostic means 415 receives inputs from the various vehicle sites via a plurality of communication lines 460 and, after interpreting the inputs and generating formatted operational information, passes the operational information to memory 420 via communication line 465.

5 Diagnostic modules suitable for use in the present invention are known in the art and are referred to as Electronic Control Modules (ECM) or Electronic Control Units (ECU). The specifications for the diagnostic modules may be found in Society of Automotive Engineers, "On-Board Diagnostics for Light and Medium Duty Vehicle, Standards Manual" 1997 Edition, the contents of which are incorporated herein by reference.

10 Memory 420 may be any conventional computer memory, the size and operation of which will be dependent on the nature of the operational features of the vehicle a user wishes to monitor. The choice of suitable memory is believed to be within the purview of a person of skill in the art. In one embodiment of the present invention, system 410 comprises a memory 420 which includes 32k of non-volatile RAM and a
15 configurable amount of additional RAM, allocated at run-time from the host processor system. Memory 420 receives the operational information, generated by diagnostic means 415, via communication line 465 and stores the operational information. Memory means 420 is in communication with server 420 and is capable of receiving instructions from server 425 and sending information to server 425 via communication lines 470a and
20 470b, respectively. As will be apparent to a person of skill in the art, communication lines 470a and 470b may be replaced by a single communication line if the appropriate communication protocol is used.

Server 425 acts as a gateway between remote client 430 and diagnostic means 415 and eliminates the requirement that remote client 430 has knowledge of the
25 specialist OBD protocols of diagnostic means 415. Server 425 in effect acts as a "universal translator", allowing a remote client to interact with any diagnostic means of any vehicle. One way of achieving this end is through the implementation of a

request/response protocol which acts as a proxy for the corresponding OBD protocols. Under this type of protocol, an abstract request from the remote client which is received by the server is mapped to the corresponding request under the specialist OBD protocols and is then transmitted on the diagnostic means or memory, as appropriate. In the other
5 direction, the responses returned by the diagnostic means or memory to the server are then mapped to an abstract response which is sent back to the client.

Such request/response protocols are known in the art and include, for example, IAS protocol for infrared links and UDP/IP protocol for wide area network communications.

10 Data link 435 may be any conventional communication link, including, for example, telephony (wired and mobile wireless), specialized mobile radio (SMR), infrared and satellite (both low earth orbit (LEO) and geosynchronous). Server 425 may be provided with the hardware and operational protocols necessary for communicating
15 with remote client 430 by a variety of means, thereby not restricting communication to a remote client having one particular type of data link. Providing server 425 with a plurality of communication protocols aids in making the system of the present invention universally acceptable.

In one embodiment, server 425 is provided with infrared data link
20 capabilities. An infrared data link between the server and the remote client provides a local wireless method of acquiring data from an OBD module. It therefore removes the need for the client's equipment to incorporate a system-compatible connector (i.e., an OBD-connector as specified by the SAE) and to be physically joined by a cable in order to communicate with the system.

25 When, for example, the client is test equipment in a garage, the use of an infrared data link renders possible the development of service bays where information can

be transferred almost instantaneously from the vehicle to the service technician's computer without requiring the customer to get out of the vehicle. The infrared connection may be achieved by attaching a serial infrared connector to a serial port on the server and by ensuring that there is an unobstructed path for IR transmission between the LED's of the infrared connector and that of the service technician's computer.

As will be apparent, the reliability of an infrared data link is improved with the implementation of a robust protocol which detects transmission errors and avoids collisions by operating in a half-duplex fashion. Such protocols are known and have, for example, been implemented by computer and software manufacturers for incorporation in consumer electronic products such as micro-computers, modems and cellular phones (i.e. the IrDA stack). Suitable protocols are described in Infrared Data Association, "Serial Infrared Link Access Protocol (IrLAP)", Version 1.1, June 1996 and Infrared Data Association, "Link Management Protocol", Version 1.1, January 1996, the contents of both of which are incorporated herein by reference.

Through compliance with these infrared protocols, the server achieves a goal of rendering client test equipment independent of the OBD protocols. Accordingly, any micro-computing equipment which is infrared-aware, such as a desk-top, notebook or palm-top (Personal Digital Assistant or PDA) can effectively become a remote client.

In an alternative embodiment, the infrared data link may be replaced or enhanced by incorporating mobile wireless data links, coupled with the UDP/IP infrastructure for peer-to-peer client/server exchanges over a wide area network. This adaptation of the system extends the range of the services offered by the server beyond its capabilities with only the infrared connector and data link. The principles described in the previous sections remain the same, with the exception that access to OBD information no longer requires that the vehicle be moved within infrared detection range (typically 2-5 metres) of the test equipment. The vehicle can be in any location which is reachable on the Internet, via a mobile data link.

The system of the present invention may further comprise a means to transmit generated operational information to a remote client, in the absence of a request from the client, when the generated operational information satisfies predetermined criteria. Such transmissions of the generated operational information implies that server
5 25 effectively becomes a client with respect to a remote site which is capable of logging the transmission. This functionality can be achieved by utilizing the peer-to-peer communication architecture described above and is useful in, for example, alarm/emergency situations.

If, for example, while monitoring the exhaust emissions of a vehicle on the
10 road, the level of carbon monoxide in the exhaust gases exceeds a predetermined level, the diagnostic means can communicate this information directly to server 125 via communication line 175. Server 125 can then transmit an alarm report to a remote site
advising of the problem. This report can be transmitted in real-time, allowing the problem to be dealt with immediately, rather than having to wait until the vehicle
15 undergoes routine servicing and diagnosis, days or even months after the problem has first come to light.

It is envisioned that the threshold values for alarms, as well as the frequency and duration of the alarm message, can be configured either directly at the server during installation or servicing, or by using remote commands from the client.

20 The system described herein may also incorporate Internet access technology for the drivers or passengers. The existing method of Internet access for individual personal computers (PC) is well-known. The PC establishes a serial link with a computer which has a permanent Internet (IP) address. The latter computer, for the purposes of this description, can be called a gateway. The serial link is physically either
25 a direct cable connection or via a telephone circuit, using modems at both ends of the link. The PC does not have a permanent IP address. It is assigned a temporary IP address

by the gateway for the duration of the connection. Therefore, if the link is maintained via a telephone circuit, then the connection automatically terminates when the circuit is dropped and the temporarily assigned IP address ceases to be valid.

One of the conventional methods of Internet access from a vehicle follows
5 the technique described above, using an analog cellular phone and a cellular modem. By connecting the PC to the cellular modem, the driver/passenger can obtain a temporary IP address in the same fashion as with wired telephony.

Another method of Internet access from a vehicle is a technology called
10 Cellular Digital Packet Data (CDPD), which is a form of packet-switching overlaid on the existing analog cellular infrastructure in the United States. CDPD operates with a portion of the bandwidth of the analog cellular system and provides a multiple access data link technology within each cellular base station's territory of coverage. However, contrary to the method already described, the network architecture of CDPD also allows each access
15 device (CDPD modem) to have its own permanent IP address. Therefore, no dial-up connection is required to establish the presence of the PC on the Internet. It suffices for the PC to be connected to the CDPD modem (which is typically in the form of a credit-card style PCMCIA card) for any Internet traffic from another location to reach the PC.

IP V6 is a new version of the Internet Protocol. One of the design
objectives of IP V6 is to enable portable computing devices (notebooks, palm-tops, etc.)
20 to have permanent IP addresses which can be reached regardless of where the portable device is physically connected to the Internet. Therefore, the device could be connected, at different times, to both an office LAN (Local Area Network) as well as a residential LAN, without requiring manual intervention by a network administrator in either LAN to ensure delivery of Internet traffic. This is achieved by ensuring that both LAN's have at
25 least one node (computer) which acts as a "Mobility Agent". The Mobility Agent incorporates software which implements IP V6 and related protocols. The purpose of the

mobility-related functions in this software is to ensure that roaming computing devices are automatically "discovered" when they establish a link to the Mobility Agent and that the rest of the Internet is informed of the new path which must be used to route traffic to the roaming device. Only those routers in the Internet which have been upgraded to
5 support IP V6 will participate in this function.

A Mobility Agent can reside in a mobile environment as well as a fixed LAN. This scenario is a distinct departure from the existing models of Internet access already described. A mobile Mobility Agent, installed in a vehicle in the form of a mobile computer, can effectively "host" any IP V6-enable portable computing device, provided
10 that it has a wireless data link to a network which is capable of routing packets on the Internet, such as CDPD. The implication is that if a vehicle is equipped with a Mobility Agent using, for instance, CDPD, then any portable device which a driver or passenger wishes to use in the vehicle to obtain access to the Internet does not also need the CDPD modem. It only requires the IP V6 software.

15 In order to equip any vehicle with IP V6 support, a hardware platform is required to host all of the required protocols and to provide the data links for portable devices trying to connect to the Mobility Agent. In order to support the SAE diagnostic test modes in the remote fashion described herein, the server contains all of the components which will also allow it to function as a mobile Mobility Agent.

20 It is envisioned that the Infrared port (and IrDA protocols), which is primarily useful for OBD diagnostic test modes while the vehicle is stationary and being examined, can "double" as an in-vehicle wireless point of entry to the internet for portable devices operated by the driver/passengers.

Another embodiment is shown in figures 8a, 8b which provides an
25 integrated circuit board for a vehicular computing device which supports the following:

- a) Acquisition of diagnostic data via an automotive data bus interface (or directly through analog and digital inputs) and storage of the data.
- b) Data communications using spread spectrum radio in accordance with the IEEE 802.11 specification for wireless local area networks.
- 5 c) Reception of signals from Global Positioning System satellites and determination of position, heading and speed based on these signals.
- d) The IEEE 802.11 protocol stack is implemented in an additional task executed by the host CPU. Depending on the choice of processing resources, the GPS position determination may be carried out by an additional task executed by the
- 10 host CPU.

In both Figures 8a) and 8b), the CPU board 510 comprises the Universal OBD Server host system into which both the spread spectrum modem and GPS receiver functions are integrated in the form of chipsets.

15 In Figure 8a), spread spectrum transceiver circuitry 512 comprises the RF processing functions required for implementation of a spread spectrum radio modem. These are embodied in a series of semiconductor devices constituting a chipset for integration of spread spectrum radio in a host CPU board. As these devices constitute externally defined components that are integrated in the present invention, only those components that interface with the host system are numbered.

20 Host CPU 520 communicates with spread spectrum transceiver circuitry 512 through two (2) serial interfaces. Serial interface 514 handles inbound data received from the sequence generator 516 while serial interface 518 handles outbound data sent to the decimator 519.

The embedded software required to drive the spread spectrum transceiver is an implementation of the IEEE 802.11 specification, executed by the host CPU. The functional interface between the host CPU and the spread spectrum sub-system corresponds to the interface between the two bottom layers of the IEEE 802.11 physical layer architecture. The lower layer is called the Physical Medium Dependent (PMD) sub-layer, which is embodied in the spread spectrum transceiver circuitry. The upper layer is called the Physical Layer Convergence Procedure (PLCP) sub-layer, which constitutes the lowest level of the protocol stack implemented in software to be executed by the host system.

Similarly, in Figure 8 b), GPS reception circuitry 542 comprises the RF processing functions required for implementation of a GPS receiver. These are embodied in a series of semiconductor devices constituting a chipset for implementation of a GPS receiver. As these devices constitute externally defined components that are integrated in the present invention, only those components that interface with the host system are numbered.

Yet another embodiment is shown in figures 9 to 15. The term "*Automotive Telemetry*" refers to the conveyance of operational data from a mobile vehicle to a regulatory or maintenance authority as well as to other, neighboring mobile vehicles. The data transmitted are acquired directly from analog and digital sensors, the in-vehicle data bus, ECU and from a GPS receiver. The data are conveyed via a wireless packet-oriented data links provided by terrestrial RF packet networks, spread spectrum and satellite.

An Automotive Telemetry System according to the present invention may be configured to enable interested parties (regulatory agencies, OEM's, dealers) to obtain critical automotive performance information in a wireless manner. It is believed that a system according to the present invention may also be configured to enable:

– reliable, substantially error-free data communications between the on-board CPU and persistent data storage;

5 - high-level services in the form of API's (Application Programmer Interfaces) for real-time alarm monitoring, trending and back-office decision-support systems. IT developers responsible for maintenance, performance monitoring and automotive engineering systems can invoke high-level services that make the CAN-bus, or any sensors and actuators, appear as though they are directly connected to the fixed-location host system.

10 - flexible communications architecture enabling many-to-many, simultaneous, multiple virtual connections between on-board CPU's and fixed-location host systems. This means that both the on-board CPU and the ground-based workstation can maintain client-server relationships with several peers at the same time.

15 on-board filtering intelligence and remote configuration capability. The on-board CPU should have the ability to restrict real-time transmission of diagnostic data according to threshold levels that can be dynamically changed from a fixed-location host. In addition, the host should also be able to remotely configure the frequency and duration of telemetry reports as well as logging to nonvolatile ram (NOVRAM);

20 - minimal use of wireless bandwidth. There is an inherent economic cost associated with the deployment of infrastructures supporting wireless data links, regardless of the method used to recover this cost. Therefore both the application

and the communication software should, where possible, minimize the use of these links through such methods as exception-driven reporting and data compression.

An exemplified system according to the present invention has three components:

- 5 - Universal On-Board Diagnostic (UOBD) Server (in-vehicle telemetry computer)
- Communications Protocol Stack
- Application Programmer Interface (API)

 A hardware instantiation of the in-vehicle UOBD Server has been built
10 based on an embedded 80386 CPU and a hard real-time multitasking kernel. The current model incorporates the following features:

- 512KB flash memory (192 KB for data logging)
- 512 SRAM
- 8 A/D channels for analog sensor inputs
- 15 - 8 digital channels for discrete inputs (each channel configurable as an output)
- CAN-interface
- RS-485 serial ports for interface to J-1708 bus (heavy trucks and buses)
- 2 RS-232 ports for PPP and/or IrDA (InfraRed) connections with external computing devices.
- 20 - GPS receiver with NMEA-compliant data link to the CPU
- RF packet radio network interface (Mobitex or ARDIS)

- Spread spectrum data link (2.4 GHz ISM band, frequency hopping CMA/CA protocol)

Real-Time Executive

5 The operating kernel adopted for the UOBD is RTEMS (Real-time executive for multi-processor systems). However, the entire body of software embedded in the UOBD (with the exception of the real-time kernel itself and bootstrapping code) is capable of running in alternative operating environments. This is achieved through the definition of an abstract operating system in terms of an object-oriented abstract base class, with specific instantiations for whatever operating environments are required.

10 In particular, a Windows NT instantiation of the operating environment has been developed for emulation and testing of the embedded system.

Communications Sub-System

15 The communications sub-system is a protocol stack which supports any combination of terrestrial RF packet network, satcom packet networks and short-range spread spectrum data links. As shown in Figure 9, the software architecture treats each wireless data link as part of a sub-network according to the Internet paradigm.

 The Internet standards are implemented within the protocol stack so that, if required, the UOBD Server can become addressable on the Internet. Internet accessibility to the UOBD Server is an option which facilitates remote diagnostics by a

variety of authorized clients. The protocol capabilities of the device include both PPP and IrDA (InfraRed) which provide connectivity to other devices in the vehicle such as palm-tops or notebook computers.

5 The architecture of the communications sub-system is designed to provide an infrastructure for "seamless" peer-to-peer communications between the vehicle and a fixed-location host system or another vehicle.

The following sections describe the various layers of the protocol stack in more detail.

Session Layer: Automotive Telemetry Protocol

10 The Automotive Telemetry Protocol (ATP) provides a simple and effective bi-directional request-response mechanism. From the vehicle, ATP allows the diagnostic monitor embedded in the UOBD Server to report fault conditions to a host system application. In the reverse direction, diagnostic inquiries and parameter configurations can be issued from the host. The ATP message syntax is similar to that of SNMP and contains
15 streamed versions of Object Identifiers (OID's) as a means of specifying the performance or operational parameter to which the message pertains.

Figure 10 illustrates this mechanism with the request initiated from a fixed location host. However, the implementation of the ATP supports both client and server functionality in either the host or the UOBD Server. As such, the UOBD Server may provide
20 simultaneous OBD services to more than one (authorized) OBD "client".

Sub-net and DataLink Layers: Hybrid RF

Short-range spread spectrum data links provide a powerful complement to RF packet networks for vehicle-to-vehicle telemetry and a potentially low-cost mechanism for OBD-III compliance monitoring. The UOBD incorporates both technologies with the intelligence to switch between them on a "least-cost" basis. In order to preserve the IP addressing mechanism allowing for a unique IP address at the interface between the UOBD Server's IP module and the drivers for its wireless data links, the present system has implemented the concept of

- an *Hybrid Network*, which is an abstraction that combines multiple physical data links. This is illustrated in Figure 11.

Any node on a *Hybrid Network* is either an in-vehicle UOBD Server or a Hybrid Network Gateway (HNG). This is a ground-based IP gateway to the *Hybrid Network* and is functionally symmetrical to the UOBD Server. It has an IP module bound to a network interface for the *Hybrid Network*. This network interface has a unique IP address.

The current HNG resides on a dedicated Windows NT workstation and effectively provides an IP-level gateway between the Hybrid Network and the rest of the Internet or corporate Intranet.

The complete protocol stack for a hybrid network node is illustrated in Figure 9. At the lowest level of this stack are data link drivers for RF packet networks. A combination of such data links is subsumed by a single abstract Hybrid Network interface, which is responsible for switching outbound transmissions over the least-cost data link in a manner that is transparent to the IP. The "cost" of using any given wireless data link is expressed as a measure of "impedance", which is established in terms of the monetary cost of transmission and of the availability of service.

Figure 12 illustrates the mechanism implemented for switching of mobile-originated frames over the least-cost wireless data link. Note that this describes the protocol behavior only at the data link layer of the stack. The behavior of the stack at other layers is described hereinbelow.

5 In part (a) of Figure 12, the UOBD CPU sends a frame over the serial link to the primary RF radio modem (spread spectrum), which in turn successfully sends it over the airlink to a base radio modem (spread spectrum access point). From there, the payload is sent to the Hybrid Network Gateway from where it can be routed over a network backbone (possibly the Internet) to a host system.

10 Part (b) of Figure 12 shows the instance where a mobile-originated frame fails to traverse the airlink. In this instance, a failure notification is received, either from the radio modem, or from a timer expiry within the CPU. The failure notification is propagated back up the protocol stack to the process which was responsible for the message contained in the frame (e.g. the ATP client or server process), which can then choose to reschedule the
15 transmission. The failure notification also causes the impedance level for the destination address to be raised to a maximum level. The retry is therefore carried out over the alternate RF data link. The impedance will be lowered whenever a notification is received that the mobile has returned within "RF range" of the base.

Network Layer: In-Vehicle Routing and IP Header Compression

20 The IP implementation is intended to enable the UOBD Server to act as a gateway from the wireless Hybrid Network to a subnet of computing devices used within the vehicle. The data link used for any of the devices is PPP (point-to-point protocol) over an RS-232 serial connection. This is designed to support a palm-top or notebook computer using PPP with a direct serial link to obtain a temporary IP address.

In many cases, the Automotive Telemetry System does not encompass more than one host site (client). The mobile UOBD Servers do not therefore need to distinguish between remote addresses. Furthermore, the Hybrid Network Gateway has address tables for resolving all IP addresses to unique physical addresses, associated with each of the RF data links, for each UOBD. Therefore, mobile-terminated datagrams do not require an explicit destination address in transmission. Similarly, mobile-originated datagrams do not require an explicit source address in transmission. In these cases, the IP headers can be compressed from 20 to 3 bytes, without loss of information. The overhead of 3 bytes is necessary to provide a sequence number for the datagram, an identifier for the transport protocol to be used and the in-vehicle subnet address of the destination. Regardless of the protocol, this amount of overhead would be required in any event.

The IP implementation supports varying levels of compression simultaneously. Telemetry traffic from a "well-known" client is subject to full compression as described above, whereas "external" Internet traffic must preserve more header information.

Transport Layer: UDP and ICMP

There are two basic types of transport protocol: "stream-oriented" and "datagram". The corresponding specifications commonly used in conjunction with the Internet are called, respectively, TCP (Transport Control Protocol) and UDP (User Datagram Protocol)

When the quantities of data transmitted are very small, relative to the maximum size of individual packets allowed over the wireless data links, the transport mechanism used is UDP. Typically, this is applied in a « request/response » mechanism one of the following three (3) scenarios :

- Host « requests » data for a specific parameter - UOBD Server « responds »
- UOBD Server reports alarm value for a specific parameter - Host confirms alarm received
- Host « commands » UOBD Server to set new configuration value - UOBD Server confirms setting.

The transport-level protocols included in the stack are UDP (User Datagram Protocol) and ICMP (Internet Control and Message Protocol). UDP supports the Automotive Telemetry Protocol in a manner identical to its use in other request/response protocols such as SNMP.

In contrast to UDP, TCP/IP provides what is commonly referred to as a « reliable, stream-oriented, virtual circuit ». Variable quantities of data can be pushed into the circuit at one end, and will be delivered at the other end in the same sequence that they were submitted. If errors occur, or individual packets traversing the actual physical networks are lost, the TCP/IP protocol stack is responsible for re-transmission. However, this is not manifest to the application software using the circuit. At each end of the circuit (called a « socket ») , all that is understood is two steady « streams » of octets (bytes) : one for reception and one for transmission.

The successful operation of TCP/IP requires significant « overhead », i.e. octets which are not part of the deliverable « payload » but are used for addressing, routing and retransmission control. Therefore, in a network environment where transmission of each packet is relatively expensive, such as RF TCP/IP should be used frugally.

ICMP is used as an error reporting mechanism, specifically for the case where the destination for an IP datagram cannot be reached. This mechanism is used in conjunction with a switching mechanism for directing over the least-cost wireless data link.

The use of ICMP is illustrated in Figure 13. The fixed location host sends an ATP message using UDP to the mobile. (It is irrelevant whether the ATP message is a request or a response. UDP is indifferent). The message is transported in an Internet datagram which must transit the Hybrid Network Gateway. The HNG attempts to route the datagram to the UOBD using the primary RF data link. This attempt fails because the UOBD is not currently reachable via the primary RF data link.

The HNG is not responsible for attempting a retry. Instead, it generates, on reception of the failure notification from the RF data link, an ICMP "destination unreachable" message which is sent to the source address of the original IP datagram. The ATP process (either client or server, depending on whether the ATP message was a request or a response) handling this message can reschedule a retransmission at a later time. In the meantime, the HNG will have changed the impedance level of the primary RF data link for the destination address in question. When the datagram transmission is retried, the HNG will route it through the lower impedance data link, i.e. the alternate RF data link. The impedance of the primary RF data link will return to its lower level when a registration packet is received from the mobile indicating that it is reachable, i.e. it is within "RF range".

Figure 9 also shows the TCP and IGMP protocols at the transport level. These protocols are not incorporated in the current version of the UOBD Server but they may have future roles in, respectively, "batch" data acquisition and multicast messaging to fleet groups

API

The API, as described in the system objectives, provides a platform on which application programmers can develop database systems and user interfaces. The API resides above the Automotive Telemetry Protocol at the "Presentation" layer of the stack. ATP is derived from SNMP, and therefore the API resembles an interface to SNMP. It consists of three types of objects which must be allocated and which methods must be invoked to

execute the interface. The following provides brief definitions for these objects and a conceptual outline of their use. The precise class definitions, function prototypes, initialization sequences and so on, are provided in a separate programmer's manual.

Diagnostic information Base (DIB)

5 These objects are similar to the notion of MIB (Management Information Base) used in SNMP. Each one corresponds to a specific data source from the vehicle: e.g. engine temperature, oil pressure, fuel level, etc. They have a unique OID (object identifier) and a cache variable for storing for the most recent value received from a remote vehicle. A DIB must be allocated for each data source which the application intends to monitor from
10 any given vehicle. Only one DIB is required for a given data source, regardless of the number of vehicles being monitored. In other words, DIB's are not needed for each vehicle but only for each unique type of data.

 All the DIB's are held in a container belonging to the ATP (see below). When a DIB is allocated, the user must add it to the ATP container by invoking a method of the
15 ATP.

ATP (Automotive Telemetry Protocol)

 The ATP is the object that encapsulates the UDP portion of the communications protocol stack. A method of the ATP is used to allocate a "listener", which is an ATP Server object that handles requests from unknown remote clients. If a UDP
20 message had been received from a mobile client for which no ATPClient object (see below) has been allocated, the ATPServer allocates a new ATPClient and registers it with the DIB's

ATPClient

An ATPClient should be allocated for each remote vehicle being monitored. The ATPClient needs to be "registered" with each DIB in the container belonging to the ATP.

5 Sending requests to a mobile is accomplished in two (2) steps. First, the user needs to invoke the appropriate ATPClient methods which will specify the OID, the message type (i.e. what type of command is being issued to the remote) and any data values which should be appended to the message (e.g. new thresholds for alarms). In the second step, the transmit method of the ATPClient is invoked.

10 Reception of messages from a mobile, whether requests or responses, is handled within the ATP. The user can provide a "hook" for each ATPClient to process the payload data of both requests and responses. This is registered with the ATPClient in the form of a function pointer. For processing of requests, the user-supplied function should indicate to the caller whether the data was correctly processed. For example, if the request received is to log an alarm to persistent storage and there is an error, a Boolean return code
15 should indicate FALSE. As a result, the response message to the mobile will indicate failure and appropriate action can be taken at the mobile end (i.e. rescheduling the transmission).

Design and Development Practices

Object Design

20 All software implementation is based on the object-oriented design principles of inheritance and encapsulation. This means that every module (class definition) of the software is derived from an abstract base class (with the exception of the abstract base classes themselves). This section describes the class hierarchies at the Operating System level and the data link layer of the protocol stack.

Operating Kernel

The operating system level is defined as an abstract set of services, to which user interfaces are standardized in order to facilitate rapid porting of the code to different operating environments. This is illustrated in Figure 11.

5 Figure 14 also shows various instantiations of the multi-tasking kernel, including a "device emulation" version in Windows NT.

Data Link Layer

10 All the data links in the embedded system, whether airlinks to RF packet networks or internal bus data links (CAN, J-1708) share common logic which is implemented in a generic data link object. The entire behavior which is unique to any particular data link protocol is encapsulated in class derivations of an abstract base class called a link identity.

15 This architecture, illustrated in Figure 14, is intended not only to minimize the code space required in the embedded system, but also to facilitate rapid integration of new RF data link protocols, particularly as they become available in the form of newly deployed infrastructures.

20 While this invention has been described with reference to illustrative embodiments, this description is not intended to be construed in a limiting sense. Various modifications of the illustrative embodiments as well as other embodiments will be apparent to a person of skill in the art upon reference to this description. It is therefore contemplated that the appended claims will cover any such modifications or embodiments.

APPENDIX A

- [1] Nathanson, M.. "System and Method for Providing Mobile Automotive Telemetry", August 1997. (1st Transcontech Patent Filing)
- [2] Case, J., Fedor, M., Schoffstall, M., and J. Davin. " A Simple Network Management Protocol (SNMP)". RFC 1157, May 1990.
- [3] Internet Engineering Task Force, Perkins, C. (ed.), " IPv6 Mobility Support", March 1995.
- [4] Nathanson, M., "System and Method for Hybrid Mobile Data Communications". November 1997. (2nd Transcontech Patent Filing).
- [5] Narten, T., Nordmark, E., and W. Simpson, " Neighbor Discovery for IP Version 6 (IPv6)", RFC 1970, August 1996.
- [6] Deering, S. and Hinden, R., "Internet Protocol, Version 6 (IPv6) Specification". RFC 1883, December 1995.
- [7] Conta, A. and Deering, S., "Internet Control Message Protocol (ICMPv6) for the Internet Protocol Version 6 (IPv6) Specification". RFC 1885, December 1995.

What is claimed is:

1. A method of exchanging data between a mobile node and an access point on a communication network, comprising the steps of:

5 a) providing at least two data links between the mobile node and the access point;

b) measuring impedance on each data link; and

c) transmitting said data across the data link having the lowest impedance.

2. A method as defined in claim 1, wherein a first of said data links is established on a spread spectrum band.

10 3. A method as defined in claim 1, wherein said mobile node and said access point are IEEE 802.11 compliant.

4. A method as defined in claim 1, wherein one of said data links is a satellite RF packet network.

15 5. A method as defined in claim 1, wherein one of said data links is a terrestrial RF packet network.

6. A communications system, comprising

a mobile node,

a fixed communications network having an access point.

a pair of alternative data links, each of which joins said mobile node with said access point, and

a switching unit for switching between said alternative data links to exchange data between said mobile node and said access point.

5 7. A system as defined in claim 6, wherein said mobile node is Internet addressable.

8. A system as defined in claim 6, further comprising a measuring module for measuring impedance on each of said data links, said switching unit being operable to select the data link having the least impedance.

10 9. A system as defined in claim 6, wherein both said mobile node and said access point are IEEE 802.11 compliant.

10. A system as defined in claim 6, wherein said mobile node is one of a plurality of mobile nodes on a communications network.

15 11. A system as defined in claim 10, wherein each of said mobile nodes is on a vehicle.

12. A system as defined in claim 6, wherein said fixed communications network includes a plurality of access points, wherein said data links join each mobile node with at least one access point.

20 13. A system as defined in claim 12, wherein some of said access points are located adjacent a roadway.

14. A system as defined in claim 10 wherein at least some of said mobile nodes are Internet addressable.

15. A system as defined in claim 10, wherein at least some of said mobile nodes are IPv6 addressable.

5 16. A communications network for exchanging data between a plurality of vehicles, comprising a computing unit onboard a corresponding vehicle, each computing unit operable in a first phase to broadcast enquiry messages in a region surrounding said vehicle, a second phase to receive reply messages from other vehicles in said region, a third phase to exchange status messages with selected ones of said other vehicles.

10 17. A network as defined in claim 16, wherein each computing unit includes an IEEE 802.11 node.

18. A network as defined in claim 16, wherein each computing unit exchanges data using an SNMP-derived protocol.

19. A network as defined in claim 16, wherein each node is Internet addressable.

15 20. A vehicle comprising an onboard computing unit which is operable in a first phase to broadcast neighbour solicitation messages in a region surrounding said vehicle, a second phase to receive neighbour response messages from computing units of other vehicles in said region, and a third phase to exchange status messages with computing units of selected other vehicles.

20 21. A vehicle as defined in claim 20, which is operable in a fourth phase to exchange data with a remote site.

22. A vehicle as defined in claim 21, wherein the remote site is reached through non-mobile network gateway.

23. A vehicle as defined in claim 20 wherein said computing unit includes an IEEE 802.11 node.

5 24. A vehicle as defined in claim 20, wherein said computing unit is capable of exchanging data using an SNMP protocol.

25. A hybrid communications system, comprising a wired network portion and a wireless network portion, each having a network connection node, at least two data link means between the network connection nodes, and a switch means for enabling either of the data links for data exchange between said connection nodes.

10

26. A system as defined in claim 25, further comprising measurement means for measuring impedance on said data links, said switch means being responsive to said measurement means for enabling the data link having a lower impedance.

27. A vehicle communications system having a controller, a data pathway joining said controller with a plurality of vehicle components and means for establishing a data link with other vehicles within a given region surrounding said vehicle in order to exchange data therewith.

15

28. A system as defined in claim 27, wherein said data link is operable in A spread spectrum band.

20 29. An operational event-reporting system for use by a plurality of neighboring vehicles to support IVHS comprising a plurality of communication units, each onboard a

corresponding vehicle to collect operational data from selected components thereof and to exchange data with the communication units of one or more of the neighboring vehicles.

30. A system as defined in claim 29, wherein the communication units broadcast messages on a spread spectrum band.

5 31. A method of exchanging data between a vehicle and at least one remote site, comprising the step of providing the vehicle with a transmitter and receiver capable of transmitting and receiving messages under an SNMP protocol.

32. A method as defined in claim 31, wherein the at least one data exchange site includes a neighboring vehicle.

10 33. A method as defined in claim 32, further comprising the steps of:

- exchanging discovery signals with neighboring vehicles; and
- exchanging status data with selected ones of the neighbouring vehicles.

15 34. A system for transferring data between a vehicle and a data exchange site, comprising a pair of data link means, wherein at least one of said data link means has a varying signal impedance level and switch means for switching between said data link means so that said data is transferred on the data link means having the least impedance.

35. A system as defined in claim 34, wherein a first of said data link means is operable in a spread spectrum band.

36. An extension of the hybrid RF packet network comprising:

- (i) an interface to an IEEE 802.11 data link integrated in the Hybrid Network Radio;
- (ii) an IEEE 802.11 Access Point acting as an IPv6 router and a foreign mobility agent for mobile nodes implementing Mobile IP;
- 5 (iii) an interface to a non-wireless subnetwork from which the Hybrid Network Gateway can route mobile-terminated traffic through an IEEE 802.11 Access Point; and
- (iv) a cluster intelligence module, based on the establishment of ad-hoc networks between a vehicle and its IEEE 802.11 neighbors.

10 37. The system according to claim 36, wherein mobile nodes that are ATP-enabled can exchange Internet traffic with regulatory agencies over license-free wireless data links (IEEE 802.11) whenever connections are established with Mobile IP-enabled Access Points.

15 38. The system according to claim 37, wherein the cluster intelligence module is operable using ATP from vehicular node to acquire information about the automotive behavior of any of its discovered neighbors.

39. A method of exchanging data between a mobile node and an access point on a communications network, comprising:

20 a) a step for providing at least two wireless data links between the mobile node and the access point;

b) a step for measuring impedance on each data link; and

c) a step for transmitting said data across the data link having the lowest impedance.

40. A method as defined in claim 39, wherein a first of said data links is established on a spread spectrum band.

5 41. A method as defined in claim 39, wherein the mobile node and the access point are IEEE 802.11 compliant.

42. A method as defined in claim 39, wherein one of said data links is a satellite RF packet network.

10 43. A method as defined in claim 39, wherein one of said data links is a terrestrial RF packet network.

44. A method of exchanging data between a motor vehicle and a remote station, comprising:

a) a step for providing at least two data links between the vehicle and the station;

15 b) a step for measuring impedance on each data link; and

c) a step for transmitting said data across the data link having the lowest impedance.

45. An inter-vehicle communications network, comprising at least two motor vehicles, each having an on-board control system, the system including monitoring portion

and a spread spectrum radio portion and which is operable to exchange useful vehicle operational data with the control system of the other vehicle.

46. A network as defined in claim 45 wherein each monitoring portion is capable of registering a vehicular event.

5 47. A network as defined in claim 45, wherein each control system is operable with other vehicular override systems to override a vehicle function according to a vehicular event.

48. A network as defined in claim 45, wherein each control system includes a memory portion for storing vehicle operational data of the other vehicle.

10 49. A network as defined in claim 45, further comprising at least one remote station which includes a spread spectrum radio portion to be capable of exchanging data with either of said vehicles.

50. A network as defined in claim 49, wherein the remote station is an internet access point.

15 51. A network as defined in claim 50, wherein the vehicles are operable to exchange data using an SNMP-derived protocol.

52. A network as defined in claim 49, wherein the remote station is located along a road way on which the vehicles are traveling.

20 53. A network as defined in claim 52, wherein a plurality of remote stations are located along said roadway.

54. A network as defined in claim 45, wherein each vehicle is capable of monitoring vehicular events in its own region.

55. A motor vehicle comprising an onboard general purpose computer and a spread spectrum radio, the computer operable to monitor a number of predetermined operating characteristics of the vehicle, the spread spectrum radio operable to establish a data link with a radio in at least one other neighbouring vehicle, wherein the computer is capable of identifying at least one vehicular event from data received on the data link.

56. A computer program product for operating a programmable computer system on board a motor vehicle, wherein the system includes a spread spectrum radio, comprising a computer readable medium including the computer executable steps of:

- instructing the radio to issue a signal to a region surrounding the motor vehicle;

- monitoring the radio for reply signals from other vehicles in the region; and when a reply signal is received from another vehicle,

- establishing a data link with the other vehicle; and

- exchanging operational data with the other vehicle over the data link.

57. A mobile automotive telemetry system for installation on-board a vehicle, comprising:

(i) diagnostic means for monitoring operational functions of the vehicle and generating operational information;

(ii) memory for storing the generated operational information; and

(iii) a server, in communication with the diagnostic means and the memory, the server comprising:

(a) means to receive a request from a remote client for the generated operational information;

5 (b) means to retrieve the generated operational information from the memory means; and

(c) means to transmit the generated operational information to the remote client.

10 58. The system according to claim 57, wherein the means to receive and the means to transmit are wireless communication means.

59. The system according to claim 58, wherein the wireless communication means is an infrared communication means.

15 60. The system according to claim 57, further comprising a means to transmit generated operational information to a remote client, in absence of a request from the client, when the generated operational information satisfies predetermined criteria.

61. The system according to claim 57, further comprising an Internet access means.

62. The system according to claim 61, wherein the Internet access means is compliant with IP V6 internet protocol and allows the server to act as a mobility agent.

20 63. The system according to claim 57, further comprising means to interface to a global positioning system (GPS) receiver.

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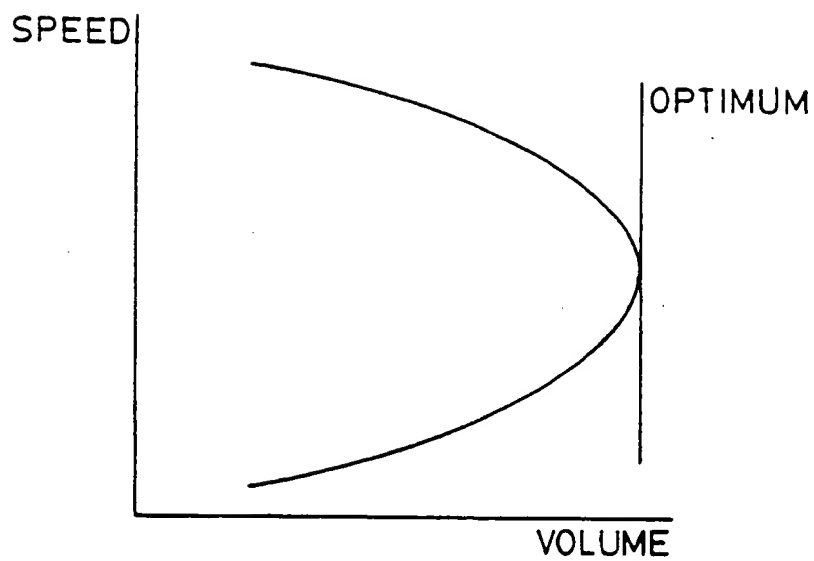


FIG. 1

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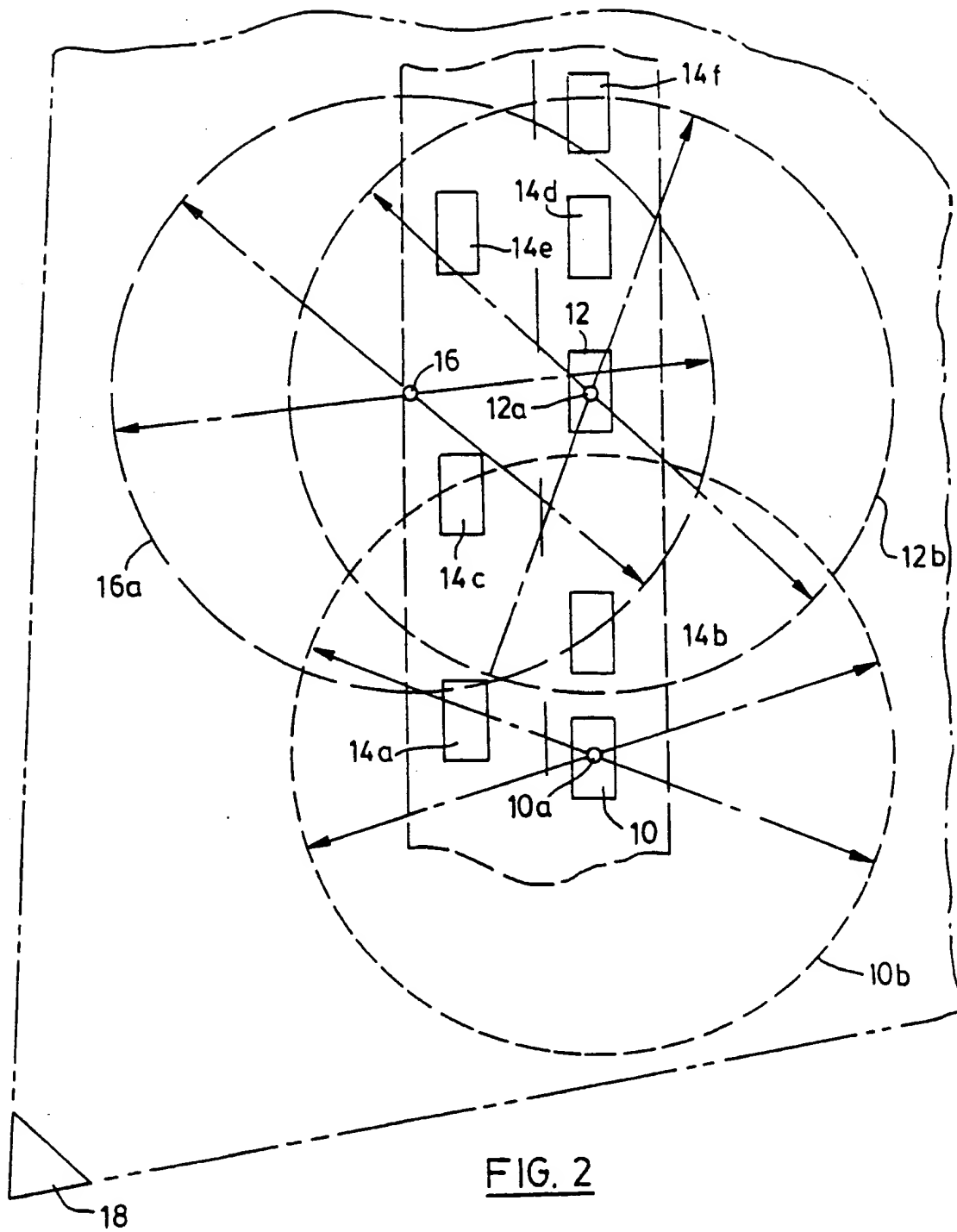
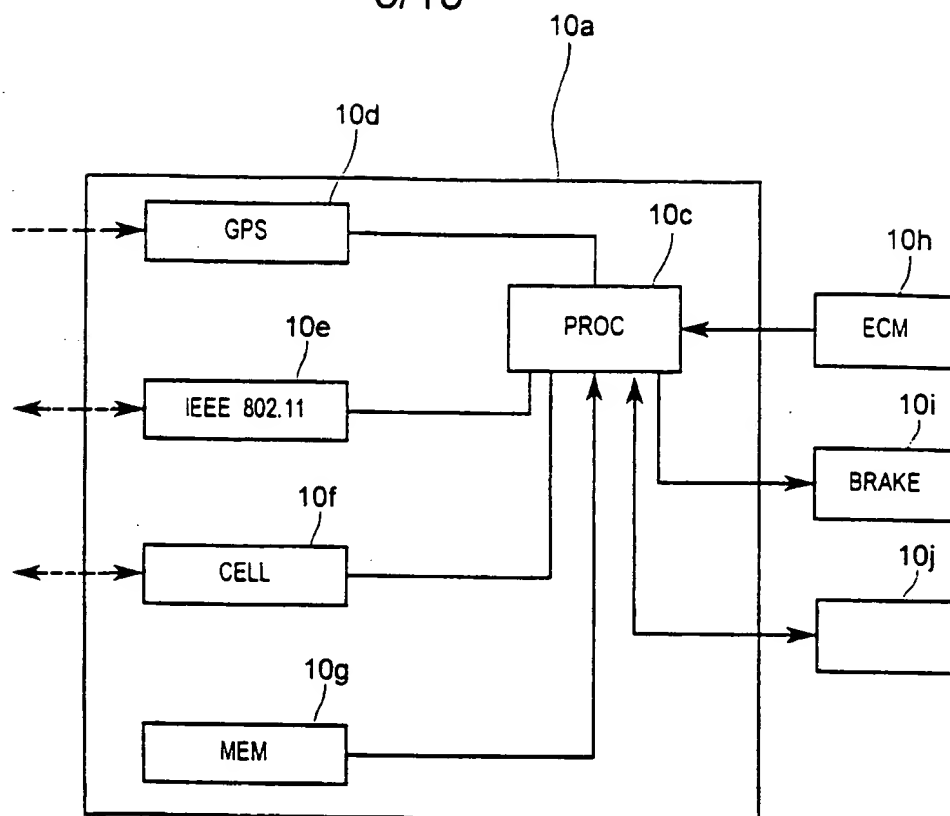


FIG. 2

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FIG. 2a

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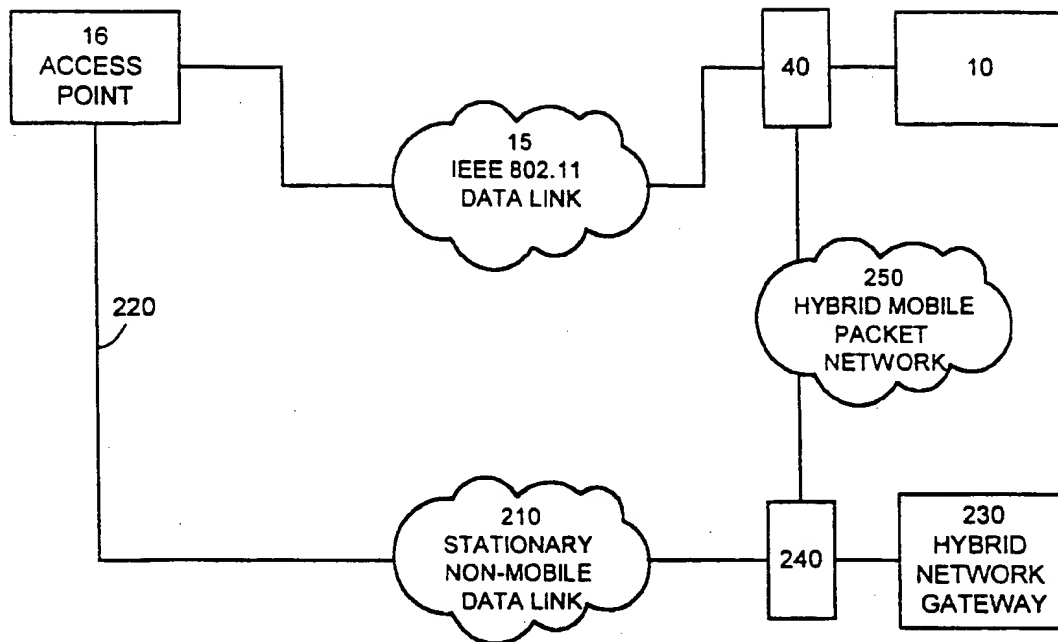


FIG. 3
Global system

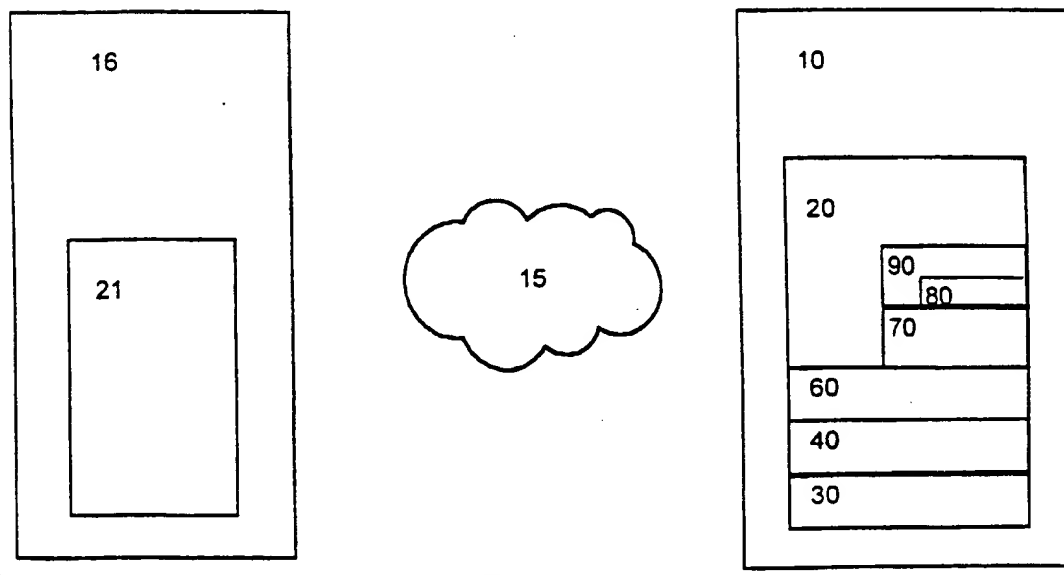


FIG. 4
IPv6 Stack for Hybrid Radio with Wireless LAN

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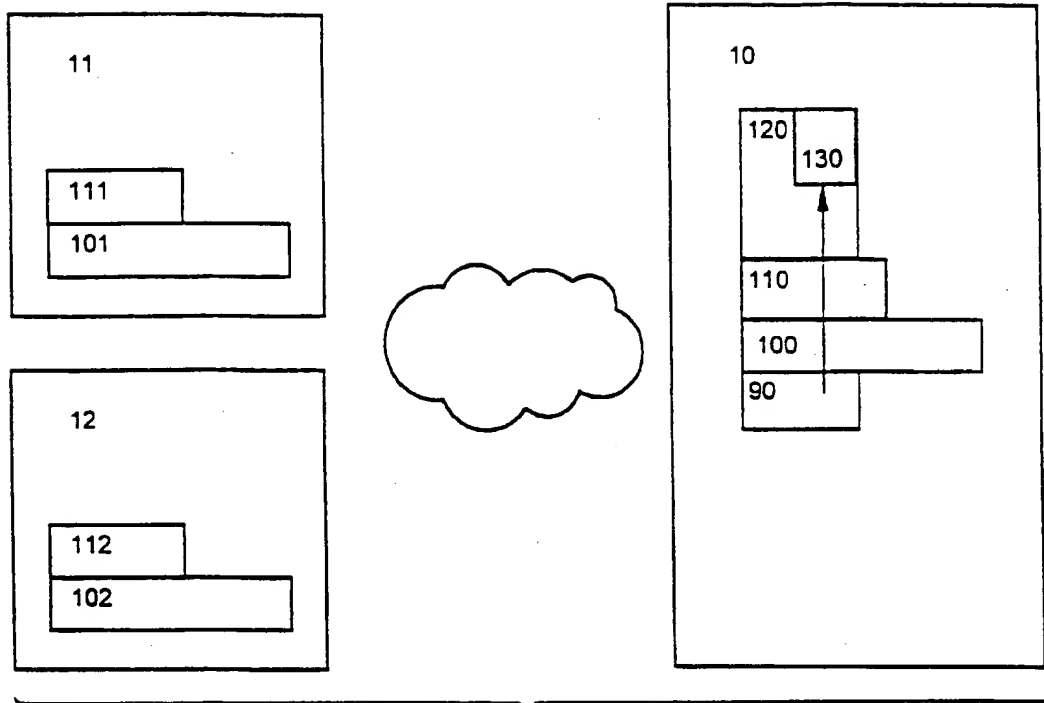


FIG. 5
Cluster Intelligence

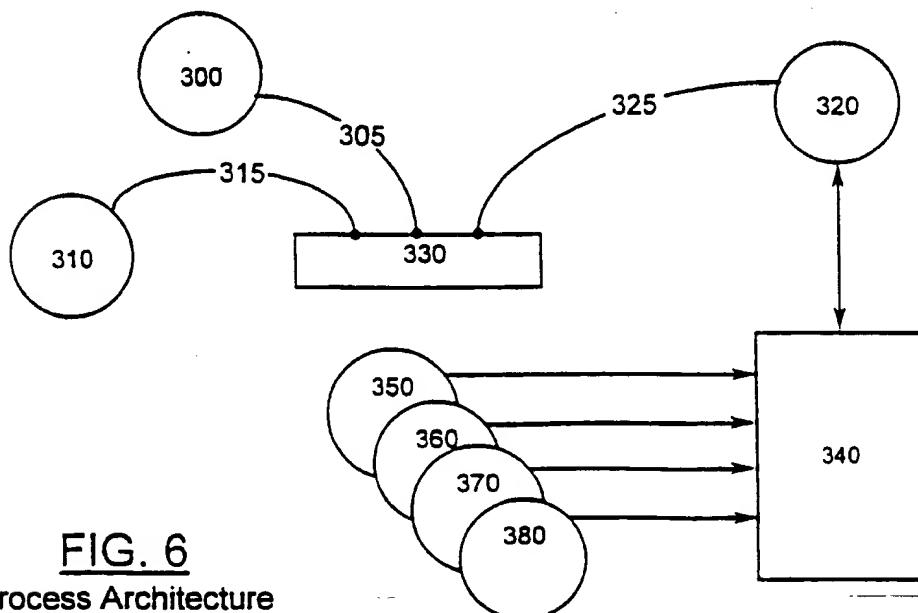


FIG. 6
Process Architecture

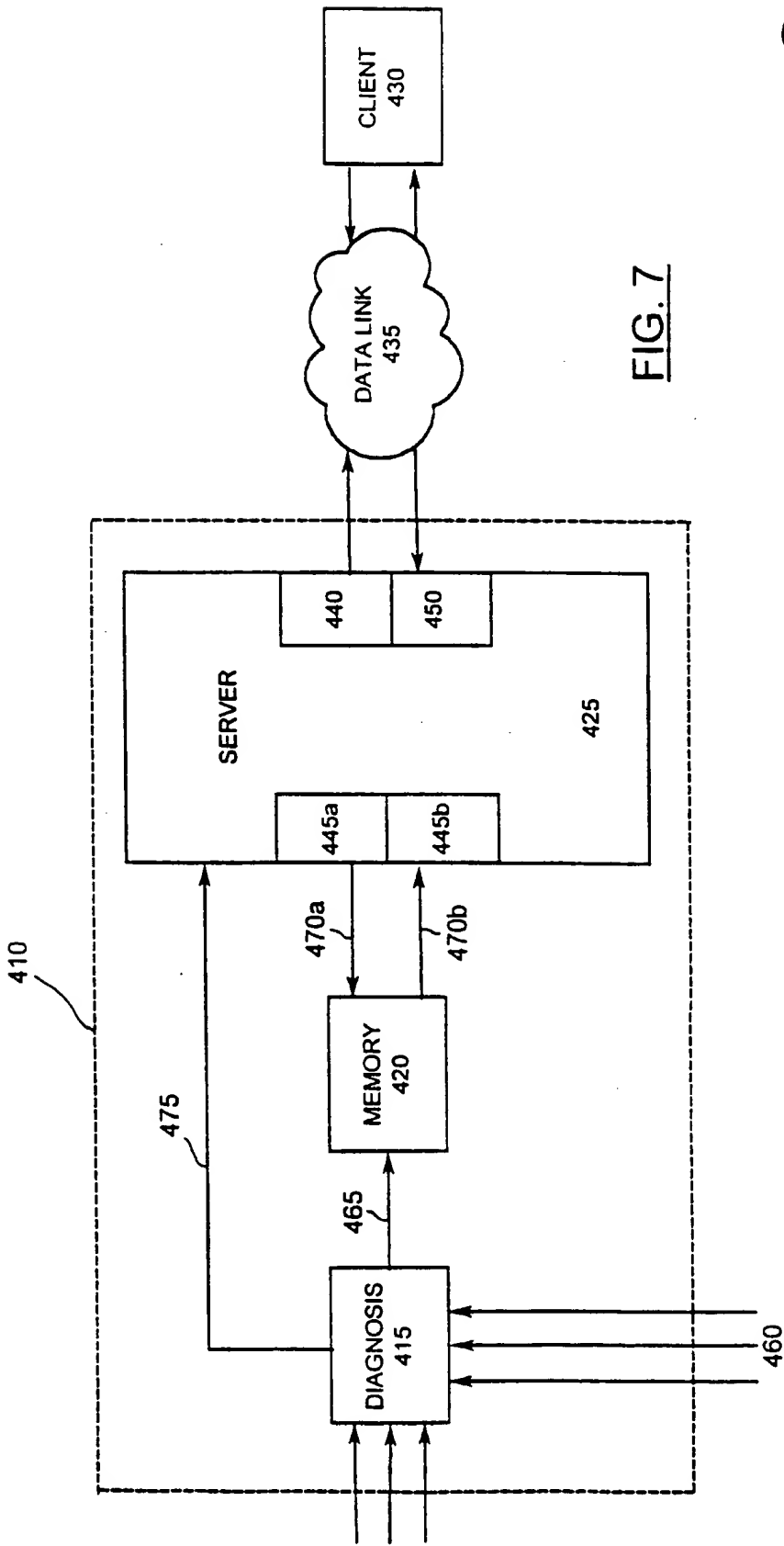


FIG. 7

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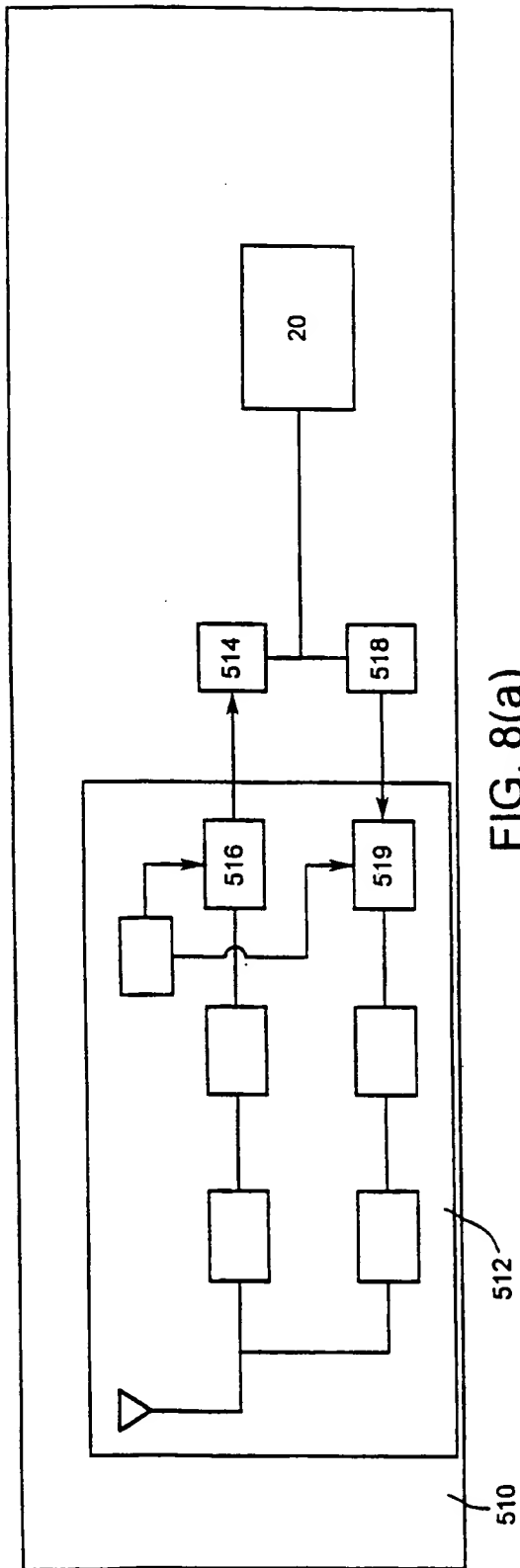


FIG. 8(a)

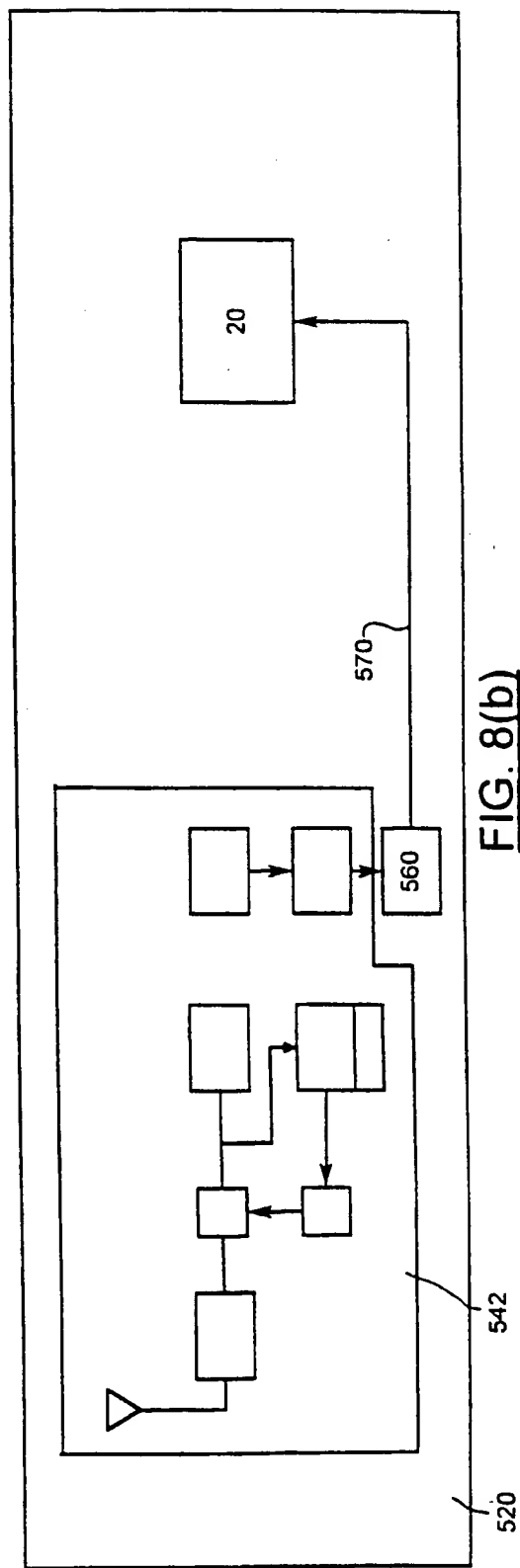


FIG. 8(b)

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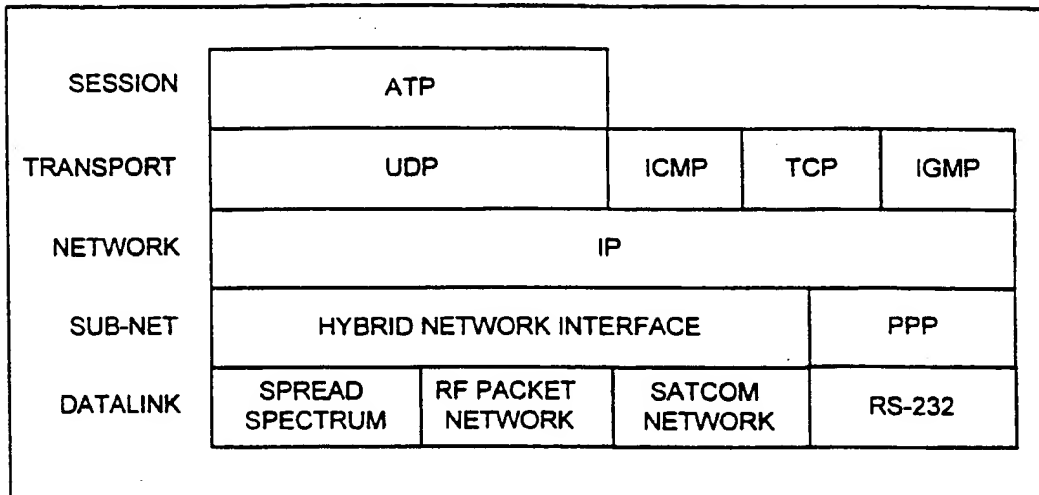


FIG. 9
Protocol Stack

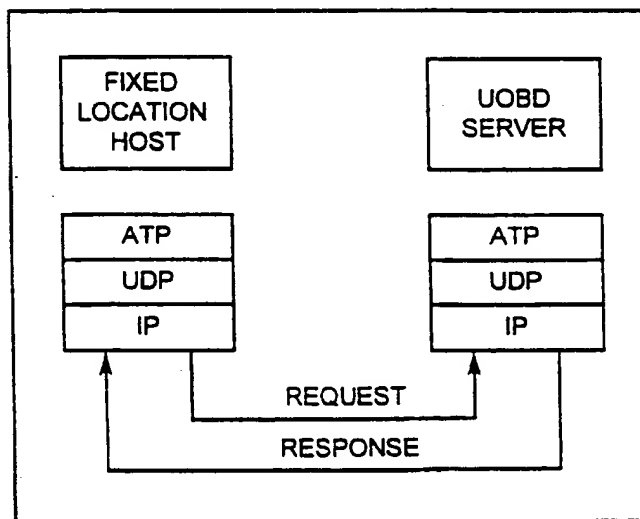


FIG. 10
Automotive Telemetry Protocol

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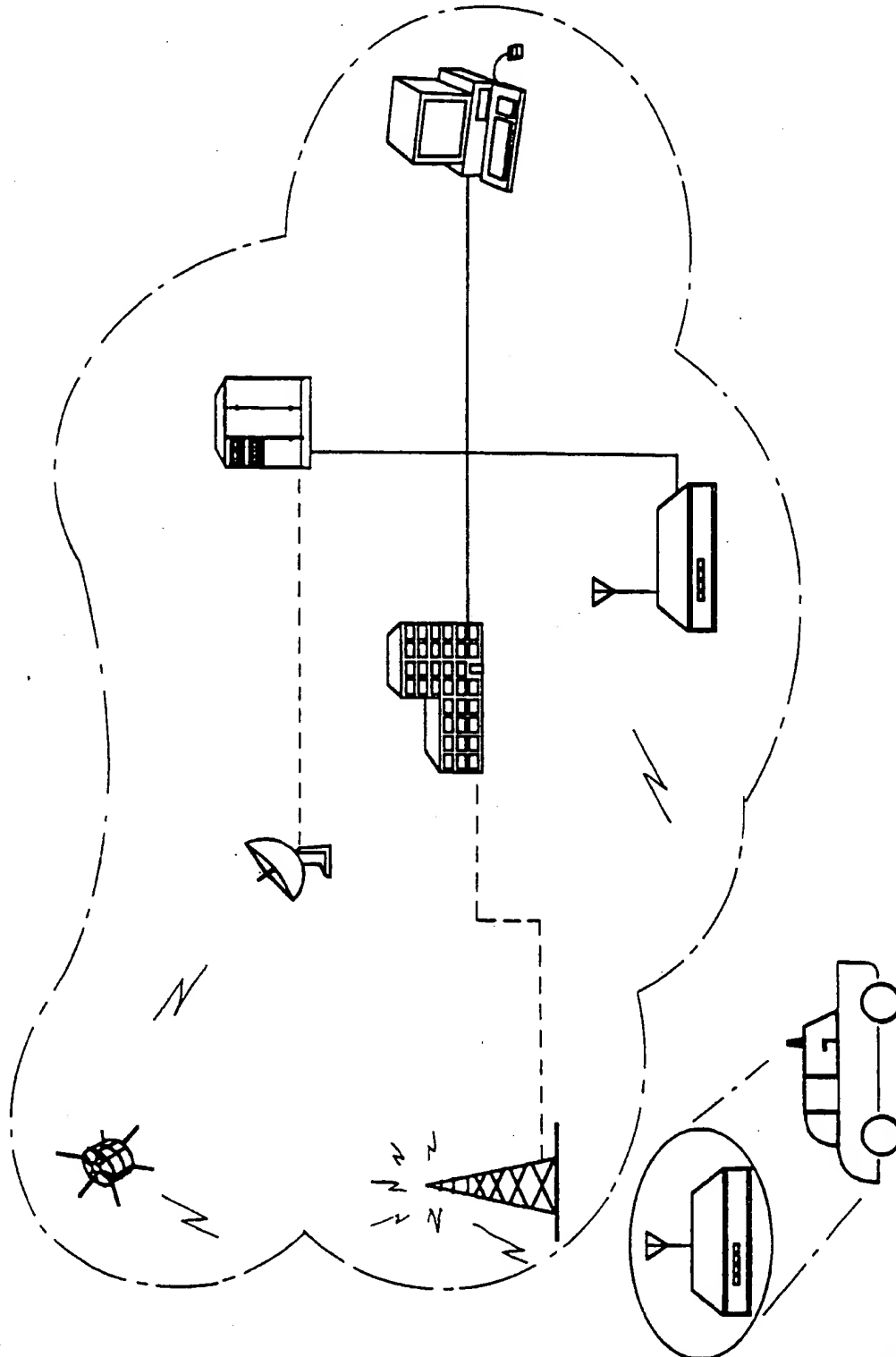
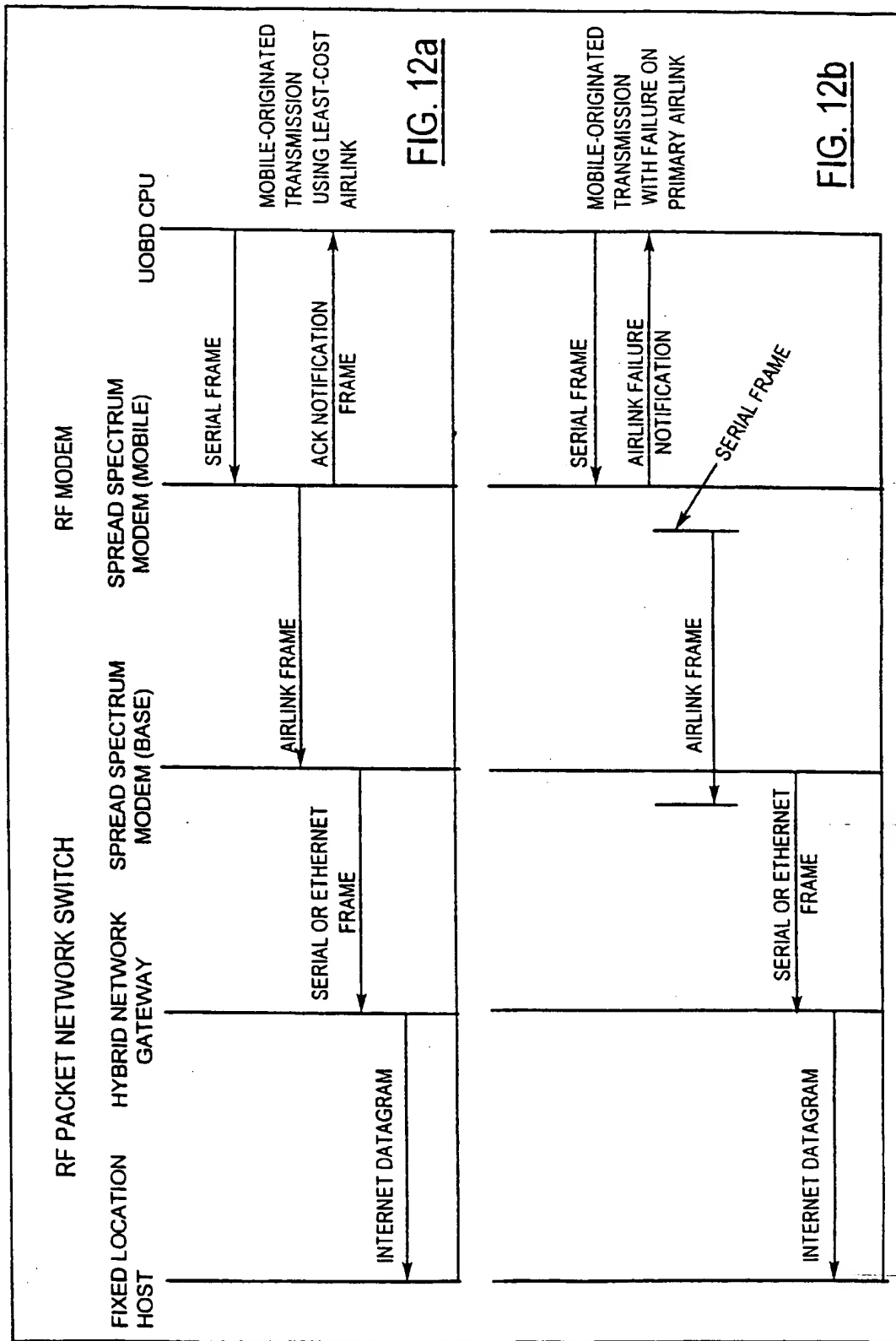


FIG. 11

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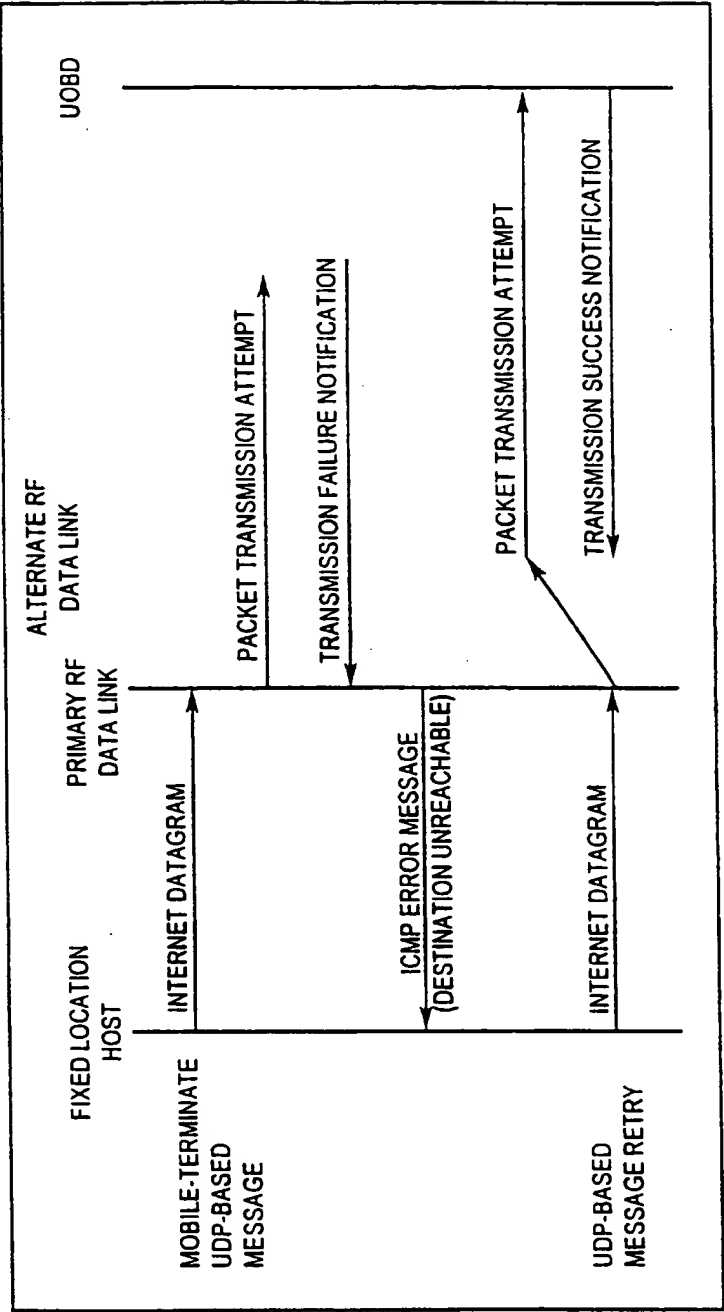
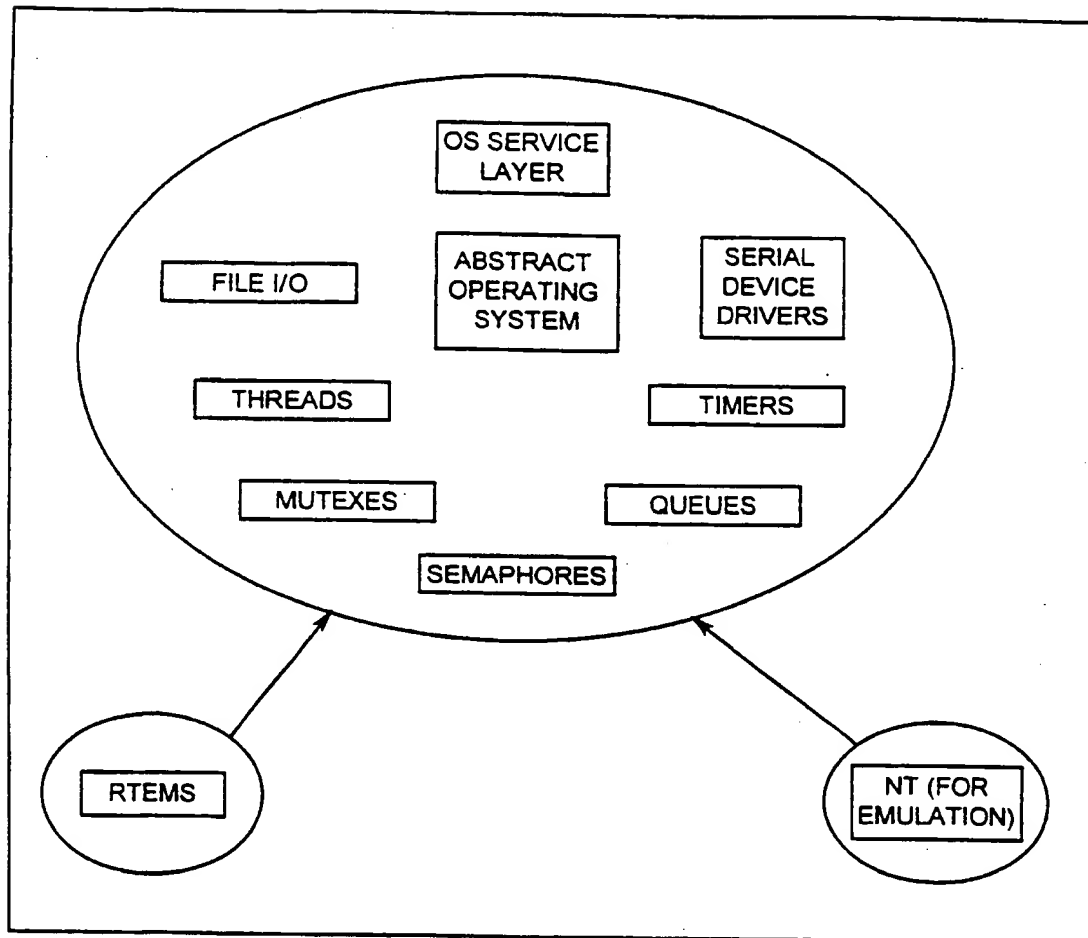


FIG. 13
Hybrid Network Gateway

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**FIG. 14**

Module Re-usability Real-time Operating Kernel

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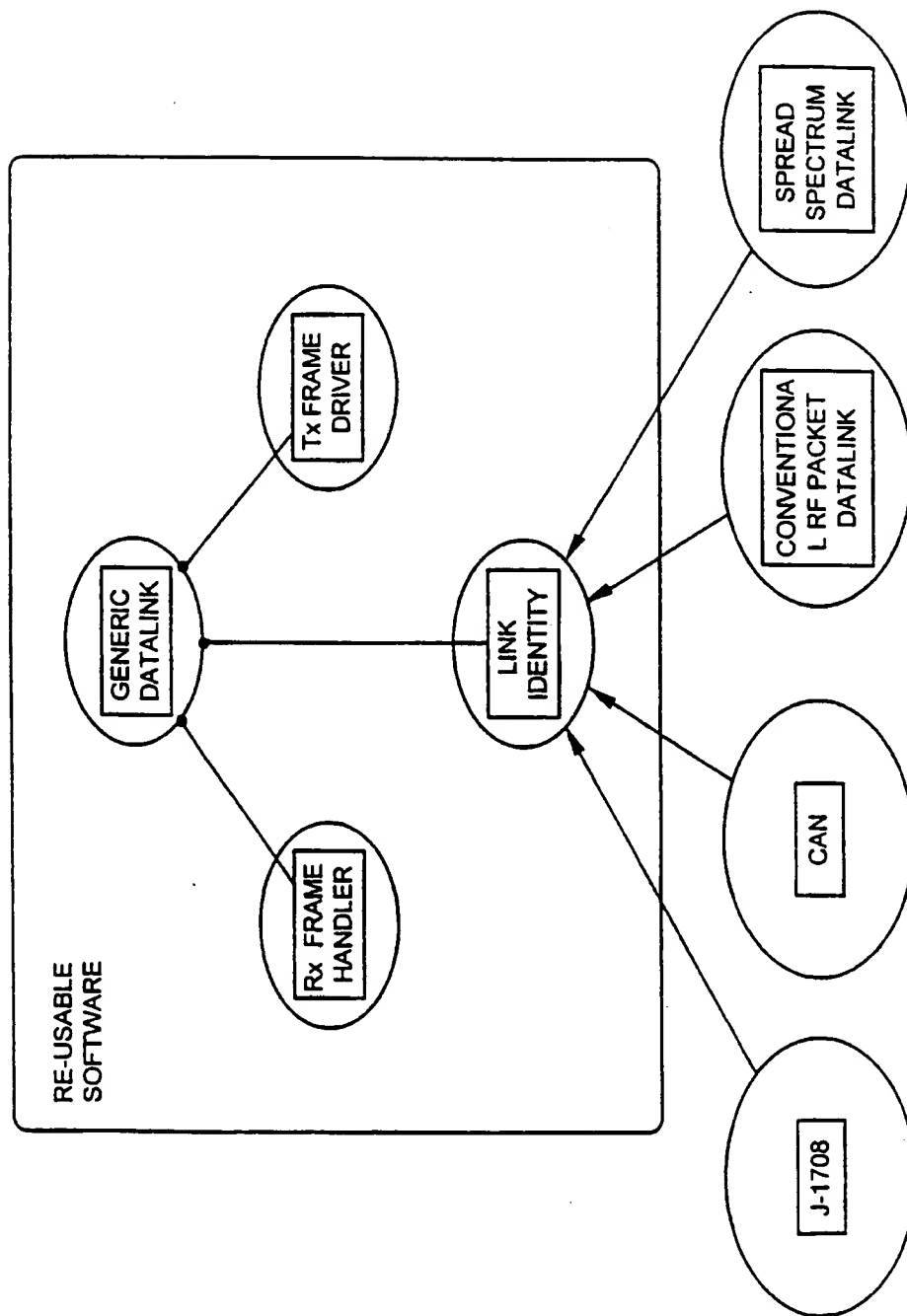


FIG. 15
Module Re-usability Data Link Layer

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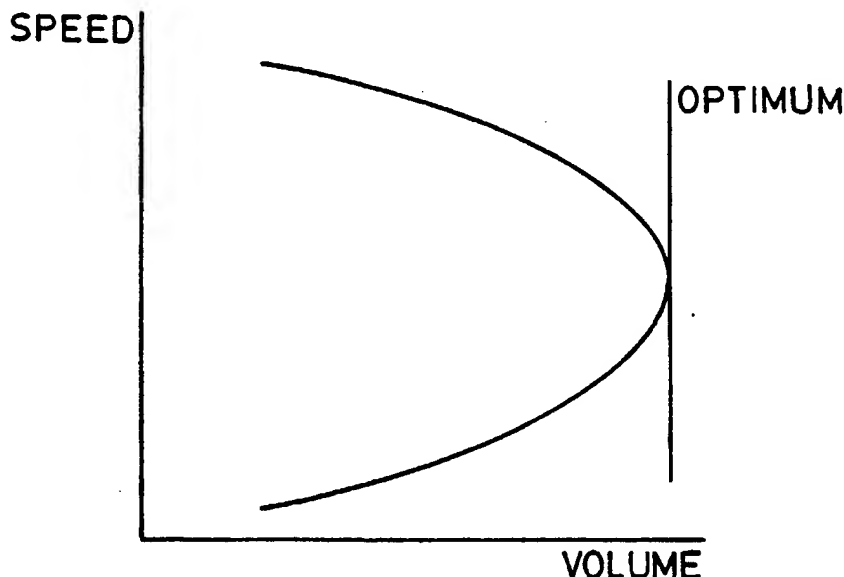
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- (74) Agents: BROWN, Peter et al.; McCarthy Tetrault, P.O. Box 48, TD Bank Tower, TD Centre, Toronto, Ontario M5K 1E6 (CA).
- (81) Designated States (national): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.
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[Continued on next page]

(54) Title: VEHICULAR TELEMETRY



(57) Abstract: The present invention provides a system for reporting on-board diagnostic data from mobile vehicles to regulatory agencies whose mandate it is to ensure compliance with environmental emissions and safety standards. The system comprises three (3) principal components: (i) an enhanced Hybrid Network Radio, enabled for both IEEE 802 wireless LAN connectivity and Mobile IP; (ii) an IEEE 802 Access Point, configured as an IPv6 Router and enabled for Mobile IP to support the functionality of foreign mobility agent; and (iii) a "cluster intelligence" module, incorporated in the same mobile device as the Hybrid Network Radio, using the Automotive Telemetry Protocol (ATP) to enable vehicles to exchange telemetry data with each other over an ad-hoc IEEE 802.11 network.

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patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

INTERNATIONAL SEARCH REPORT

Int. Appl. No.

PCT/CA 00/00712

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 H04L12/28 H04L12/56 H04Q7/38

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 H04L H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

WPI Data, PAJ, EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	---	2,3,40, 41
	-/--	

☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

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A		1,6,25, 34,39,44

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INTERNATIONAL SEARCH REPORT

Int. Application No

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Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	----- US 5 854 985 A (LEEDOM JR CHARLES M ET AL) 29 December 1998 (1998-12-29) column 1, line 8 -column 3, line 62 column 19, line 12 -column 20, line 38 claims 1,7	1,6,25, 34,39,44
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA 00/00712

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-6, 8-13, 25, 26, 34, 35, 39-44

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-6,8-13,25,26,34,35,39-44,
as far as relating to the first invention

A communications method between a mobile node and an access point, where a plurality of links are provided between said mobile and said access point, costs of each link are measured, where data is transmitted accross the link with the least costs, and where spread spectrum communications are used.

2. Claims: 6,7,14,15,
as far as relating to the second invention

A communications method between a mobile node and an access point, where a plurality of links are provided between said mobile and said access point, costs of each link are measured, where data is transmitted accross the link with the least costs, and where the mobile nodes are Internet addressable.

3. Claims: 16-24,56

A communications network for communicating between a plurality of vehicles, where a station first broadcasts an enquiry, then receives replies from other stations, and finally carries out the communication.

4. Claims: 31-33

A method of communicating between vehicles, where the communicating stations utilize SNMP protocol.

5. Claims: 36-38

An extension of a hybrid packet network, that comprises an interface to a wireless data link integrated in a hybrid network radio, a wireless access point acting as a router, a foreign mobility agent implementing Mobile IP, an interface to a non-wireless subnetwork, and a cluster intelligence module.

6. Claims: 27-30,45-55,57-63

A vehicle communications system comprising plural onboard communications devices and structures.

FURTHER INFORMATION CONTINUED FROM PCT/SA/ 210

INTERNATIONAL SEARCH REPORT

Information on patent family members

Int. Application No

PCT/CA 00/00712

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